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MINUTES OF THE EXECUTIVE COMMITTEE MEETING
April 17, 1981

The meeting was called to order by President Robert E. Henderson at 4:10 p.m. in the KW room at Turkey Run Inn, Marshall, Indiana. The minutes of the Executive Committee meeting of the Fall 1980 meeting at Saint Joseph's College were read and approved.

TREASURER'S REPORT

Treasurer John A. Ricketts presented the Academy finances as of April 12, 1981.

Current Assets

Checking Account		$ 2,493.29
Savings Account		15,340.47
	Total	$17,833.76

These are distributed in

Academy Accounts		$ 3,662.86
Administered Accounts		14,170.90
	Total	$17,833.76

Acceptance of the report was moved, seconded, and approved.

ELECTED COMMITTEE REPORTS

Academy Foundation Committee

William A. Daily, Chairman, reported that on March 31, 1981, the John W. Wright Investment Income Fund Account had $32,000, yielding approximately 13.6%. The market value of the Foundation account was $24,922 and for the John S. Wright Fund the value was $700,672, the latter representing a 17.6% increase in value.

Program Committee

Robert Henry announced that Paul C. McKinney, Co-chairman, would be in Europe until early August. Bob will act in Paul's place in arranging the Fall Meeting. Bob indicated he would ask for information from Section Chairmen regarding their plans for the Fall Meeting. The question of selection of a speaker for this meeting will be directed to the Science and Society Committee.

Academy Representative to NASS

President Robert E. Henderson reported his impressions of the AAAS meeting in Toronto. He indicated that this meeting could have handled more content. Minutes of the meeting are available from him.

Research Grants Committee

Ernest Campaigne, Chairman, reported the results of the current round of awards, along with a comparison with the results of last year. A total of 18 proposals, compared to 5, were fully funded, with 5 receiving partial funding. The total

funds awarded were $6229, compared to $6116 last year, with an average grant of $479, $42 more than last year. Unfortunately, it seemed that the quality of the proposals had dropped. The system of rating was discussed. The deadline for receipt of proposals for the Fall 1981 round of grants is September 15, 1981.

The question whether IAS would again contribute funds to supplement AAAS monies to support grants to students in secondary schools was raised. If AAAS did not provide support this year, funding in the $600 to $800 range would be needed to maintain last year's level.

Motion: That the Executive Committee approve use of up to $750 to be offset with monies received from AAAS for the purpose of awarding grants to secondary school students.

Seconded and approved.

Award date for these grants is September 15, 1981.

Emeritus Membership

Jerry Nisbet, on behalf of Robert H. Cooper, presented the names of William W. Bloom (1943) and R. Vincent Cash (1951) as fulfilling the requirements of Emeritus Membership. (Initial membership year shown in parentheses.)

Motion: That the persons presented be elected to Emeritus Membership.

Seconded and passed.

Youth Activities Committee

Jerry Nisbet, Chairman, presented the results of the February 13, 1981 meeting.

Regional Science Fairs have been completed in all 12 regions of the State. Two winners from each region along with their teacher-sponsors will attend the International Science and Engineering Fair at Milwaukee, Wisconsin, on May 11-16, 1981. Karl Kaufman of the Indiana State Department of Mental Health has expedited financial support in the amount of $10,000 through the Indiana Science Education Fund to offset travel costs to the Fair and to sustain workshops.

The Indiana Science Education Fund is providing four $1,000 scholarships plus a new $1,200 scholarship for the top senior Science Fair winner.

Walt Cory is chairing a panel of judges on April 21, 1981, charged with selection of the recipients for the four $1,000 scholarships and the recipient for the $1,200 scholarship designated as the Beth and Otis Bowen Scholarship. Awards will be announced at the International Science and Engineering Fair in Milwaukee on May 14, 1981.

Two other awards for seniors will be made for the top achievers in science in the State. Those selected will attend the National Youth Science Camp at Bartow, West Virginia.

Plans for the Fall meeting of the Junior Academy of Science are being coordinated by Keith Hunnings and Leota Skirvin.

Science Talent Search

Walter Cory announced that there had been 46 entrants and that 25 of these were interviewed and their projects judged. This is a two-day process requiring much effort.

Newsletter

Walter Cory indicated that the four issues of the Newsletter a year rate would

be maintained. A serious attempt has been made to request information through the Newsletter about those members for whom we no longer have addresses.

William Hopp commended Walt Cory for his highly efficient and effective work with the Newsletter. This was seconded unanimously by the Executive Committee.

Concerning the Science Talent Search Finalists, Ernest Campaigne noted that four or five of the finalists were funded by IAS.

William Eberly commented that there appeared to be some discrepancy between the Finalists in the Science Talent Search and those selected for the National Youth Science Camp under the auspices of Jerry Colglazier. Considerable discussion followed, with the conclusion that the students may be judged using different information and/or standards, therefore leading to different results.

Publications Committee

Donald R. Winslow, editor, reported that he had received 79 papers for publication in Vol. 90 of the *Proceedings*. These were being reviewed, some by outside reviewers. High standards would be maintained. Also noted was the fact that the long-time State publisher has gone out of business and that there currently is no State printer.

William Eberly indicated that one monograph is almost completed.

Speaker of the Year Committee

John Patton, Chairman, indicated that the term of Damian V. Schmelz to speak on "Stewardship of Indiana's Natural Resources," which had been extended due to his illness, was completed. Schmelz gave presentations at: Vincennes University, DePauw University, Franklin College, and Hanover College.

The current Speaker of the Year, Harry G. Day, has completed his scheduled appearances with presentations on "Progress in Resolving Food Safety Problems" at St. Meinrad College, Purdue University, Wabash College, and Indiana State University.

NEW BUSINESS

The question whether the Indiana Academy of Science would extend honorary membership to Governor Orr was raised. Governor Bowen was made a permanent honorary member at the 1975 Spring Meeting at which the Executive Committee was empowered to extend the honorary membership to all future Governors. It was felt that in view of Governor Orr's business background, that it would be inappropriate to recommend him for honorary membership.

Meeting adjourned at 5:51 P.M.

Respectfully submitted,

John H. Meiser
Secretary

Indiana Academy of Science
SPRING MEETING

MINUTES OF THE GENERAL SESSION
April 17, 1981

The meeting was called to order by President Robert E. Henderson at 9:08 p.m. in the KW Room at Turkey Run Inn, Marshall, Indiana.

The minutes of the Executive Committee Meeting were read and approved with corrections.

Meetings were arranged between Robert Henry and the Chairmen of the sections who were present.

For the Fall meeting a symposium on waste disposal will be held on Saturday morning. It was felt that the idea of having symposia was well received at the 1980 Fall Meeting. However, only one symposium will be held, rather than two concurrent ones.

Selection of suitable speakers for the Fall Meeting was discussed.

The meeting was adjourned at 9:30 p.m.

Respectfully, submitted,

John H. Meiser
Secretary

Indiana Academy of Science
FALL MEETING
MINUTES OF THE EXECUTIVE COMMITTEE MEETING
November 5, 1981

The meeting was called to order by President Robert E. Henderson at 7:34 p.m. in Goodrich 104 at Wabash College, Crawfordsville, Indiana. The minutes of the General Session meeting of the Spring 1981 meeting at Turkey Run Inn, Marshall, Indiana were read and approved.

TREASURER'S REPORT

Treasurer John A. Ricketts presented the Academy finances as of October 15, 1981.

Current Assets

Checking Account	$ 2,484.38
Savings Account	16,231.29
Total	$18,715.67

These are distributed in:

	Academy Accounts	Administered Accounts
Balance, 1/1/81	$ 3,127.80	$15,055.75
1981 Income	10,478.77	12,410.88
1981 Expenditures	4,792.77	17,563.76
Balance, 10/15/81	$ 8,813.80	$ 9,902.87

Membership to Date: Sustaining—35; Senior—521; Regular—238; Student—74; Clubs—12; Life—5; Emeritus—82.

ELECTED COMMITTEE REPORTS

Academy Foundation Committee

William A. Daily, Chairman, reported that on September 30, 1981 the following amounts were in the Research Endowment Fund:

Foundation Account		
Income		2,058.21
Disbursement to I.A.S. for Research		300.00
Market		23,389.19
John S. Wright Fund		
Income		$ 30,367.66
Disbursements		
I.N.B. Management Fee		2,807.00
Transfer to Invested Income Account		29,314.28
Invested Income Account		
Assets of 9/30/80		$ 73,165.04
Income 10/10/80 Through 9/30/80		8,629.35
Income Transfer from J.S.W. Fund		29,314.28
	Total	$111,108.67

Disbursements		
Proc. Vol. 89 Deficit		$ 6,765.50
Research Grants		10,766.00
Purchase of U.S. Treasury Notes		29,988.60
Transfer to J.S.W. Fund		11,694.13
At current market value of Treasury Notes ($29,565.90), assets available to use:		$ 81,463.34
	Total	$111,108.67

Current yield from commercial paper and bonds: 14.96%

Editorial Committee

Donald Winslow, editor, announced that review of 80 papers for the *Proceedings* of the I.A.S., Vol. 90, 1980 resulted in 54 papers recommended for publication. Because the State printer went out of business, the publication was submitted for individual bids. The award went to Western Newspaper Publishing Co., Inc. and is already behind schedule.

It was suggested from the floor that model abstracts be sent to authors through the chairmen of the sections.

Biological Survey Committee

Theodore J. Crovello, Chairman, reported that questionnaires for the 1980 Survey of the Annual Survey of Literature and Works in Progress Dealing with the Plants, Animals and Environments of Indiana were sent to the 69 life science departments in the State and formed the basis for the report that will appear in the *Proceedings*. The 1981 Survey is now available at this meeting.

The Indiana Rare Plant Species Survey carried out by the Academy ends on December 31, 1981. Its activities showed the cooperation possible with the Division of Nature Preserves and Natural Heritage Program of the Indiana Department of Natural Resources. The final report is being prepared.

A possible cumulative survey of literature and works in progress to be printed as part of the 1984 Centennial Celebration of the Academy was discussed.

Also introduced were proposed vegetation maps—proposed set of maps that describe the past and potential natural vegetation of the State, as well as its current vegetation and land use.

Crovello indicated that the preliminary program plans were available for the Spring meeting April 23-24, 1982 to be held at the University of Notre Dame.

Program Committee

Paul McKinney, Co-Chairman, reviewed some of the preparations for the meeting. On behalf of the Academy, President Henderson thanked him and his fellow workers for their work to make this meeting a success.

Invitations Committee

Donald J. Cook, Chairman, announced that the 1982 meetings will be held at Notre Dame. Negotiations are proceeding to have IU-PU at Fort Wayne host the 1983 meetings. The 1984 meeting will be held at Butler University.

Research Grants Committee

Ernest Campaigne, Chairman, gave a summary of awards for the March 15 and September 15 deadlines.

Academy Research Grants

A total of 23 proposals were received in 1981, 8 being fully funded with 8 partially funded. Eight institutions were represented with a total of $8,709 being awarded. The average award was $539 with a range from $200 to $990.

Secondary School Awards

Six awards were made for a total of $598. The Academy received $300 from AAAS for support of this award and supplemented that money with $298 from the research grants budget.

The use of Wright Fund monies for high school research awards was questioned. it was decided to discuss this issue at the budget meeting on December 5, 1981.

IAS Research Grants

A listing of the grantees, an abbreviated title, and the amount granted follows:

Investigator/Institution	*Title*	*Amount*
Spring, 1981		
1) *D. Adalis* Ball State	Pathological Effects of *in vivo* Exposure to Ozone in Hamsters.	$670
2) *G.J. Gastony* Indiana	Systematic Study of *Agastache* Section *Agastache* (Renewal)	$445
3) *M.E. Hults* Ball State	Shallow Bands and R.F. Wave Variation of Total Solar Eclipse	$800
4) *W.T. Jones* Purdue	Evolution of Inheritance in Heteromyid Rodents (Renewal)	$650
5) *W.T. Morgan* IUPUI	Sedimentological, Hydrological and Engineering Controls on San Dunes	$200
6) *C.E. Nelson* Indiana	Developmental Temperature and Emydine Turtle Systematics (Renewal)	$662
7) *R.R. Pinger* Ball State	Host Preference of Mosquitos Attracted to Dogs	$275
8) *Riemenschneider* IUSB	Post Wind Damage Survey of Bendix Woods	$340
9) *R. Russo* IUPUI	Effect of Starvation on Asynchronous Egg Production in Mosquitos	$500
10) *E.M. Shull* Manchester College	Butterflies and Skippers of Indiana (Renewal)	$500
11) *T.R. West* Purdue	Engineering and Environmental Geology Study of Hancock Co. Indiana	$590
12) *H.C. Womack* Ball State	Ultrastructural Changes in the Pineal Gland after Illumination Changes	$275
13) *M.T. Jackson* Indiana State	Analysis of Vegetation Composition etc., in a Flood Plain Forest	$312
Fall, 1981		
1) *E.K. Pikitch* Indiana	Forage Availability for Lake Erie Fish	$900
2) *C.H. Tomak* Mooresville (Ind. Dept. Highway)	Archaeological Research at Swan's Landing, Harrison Co., Indiana	$990
3) *T.R. West* Purdue	Statistical Methods in Rock Mass Studies	$600
	Total Recommended	$8,619

Secondary School Grants

Investigator/Institution	Title	Sponsor	Amount
Tom Beutner Marquette High School Michigan City	Improved Wind Tunnel Design	D.G. Christakis	$100
Lisa True John Adams High School South Bend	Effect of Elevated Sucrose Intake in Mice	N. Longenecker	$118
Jeff Taisey East Tipp Junior High Lafayette	Solar Energy	W.D. Hendrickson	$ 40
Matthew G. Kelty East Noble High School Kendallville	Vertical Axis Wind Generation	V. Rhodes	$100
Mathew Marquand East Noble High School Kendallville	Electromagnetic Propulsion	V. Rhodes	$ 50
Rick Meyer East Noble High School Kendallville	Control of *Dibotryon morbosum*	V. Rhodes	$120
		Total	$528
Total Grants Recommended (less $300 from AAAS)			$8,937

Nominations Committee

William B. Hopp, Chairman, presented a list of names for Academy office. It was moved, seconded, and approved to accept the nominations for presentation to the general membership.

Committee on Fellows

Daniel Webster moved approval of a slate of fellows to be presented to the membership for election to the rank of Fellow of the Indiana Academy of Science. Motion was seconded and approved.

Emeritus Selection Committee

Robert H. Cooper, Chairman, presented the following names for the election to Emeritus membership (date of first membership in parentheses):

Dr. Otto K. Behrens, Past President	(1941)
Dr. Lowell I. Dillon	(1954)
Dr. Clarence F. Dineen, Past President	(1954)
Dr. Gerald E. Doeden	(1953)
Frances M. Gourley	(1948)
Dr. Carleton W. Roberts	(1954)
Lawrence A. Schaal	(1957)
Dr. Eliot C. Williams	(1948)

Motion to approve was seconded and approved.

"Speaker of the Year" Selection Committee

Damian V. Schmelz, Chairman, announced the selection of Dr. A. Alan B. Pritsker and the acceptance of the invitation to speak at the campuses of Rose-Hulman, Huntington, and Purdue Calumet.

AAAS Representative

President Robert E. Henderson reported on his impressions at AAAS. Two things stood out. Active research at the regional level is being backed, and the association is a loose one.

Publications Committee

Benjamin Moulton, Chairman, reported that activity continues along two lines (1) continuing monograph work, and (2) Centennial Volumes. Two of the latter are in progress; "A History of the Academy" by W.A. Daily and Fay Daily, and "The Climate of Indiana" by John Oliver and Ben Moulton.

Youth Activities Committee

Jerry J. Nisbet, Chairman discussed the Indiana Science Fairs. Karl Kaufman and Lloyd Anderson have served as co-directors with 12 Regional Fairs being held. Two students, sponsoring teachers and the Regional Fair Director from each region attended the International Science and Engineering Fair at Milwaukee, May 11-16, 1981. Five scholarships were awarded to the top Indiana Science Fair Winners. This year six workshops for teachers are being held in different regions of the state supported by Lilly Endowment grant to the Indiana Science Education Fund. Keith Hunnings and Leota Skirvin have been co-directors of the Junior Academy of Science this year which is meeting concurrently with Senior Academy.

Walter Cory, Jr., director of the Indiana Science Talent Search, reported that Kappa Kappa Kappa Sorority again provided financial support for the Talent Search and awarded two $1,000 scholarships to winners of the competition which was held at the Medical Center Union Building at Indianapolis on March 13-14, 1981. Our program still generates strong interest, attracting 40-50 entries.

Newsletter Editor

Walter A. Cory, Jr., editor of the Newsletter, spoke on the problems of getting news into the public medium concerning the meetings of the Academy. Various suggestions were made from the floor. It was agreed that the newsletters are excellent and a great way to stay informed of Academy activities.

Science and Society Committee

President Robert E. Henderson spoke for William Beranek, Jr. who serves out his term this year. He complimented James M. Shuler, in particular, for the work he put into the committee.

Library Committee

Lois Burton, Chairwoman, reviewed recent accomplishments. All holdings of the Academy are being converted to the OCLC Union Listing of Serials in order to have computer access. A total of 34 new journal titles were added to the collection bring to 928 serial titles and a collection of 11,000 volumes. The number of copies of Volume 90 of the *Proceedings* will be 800 hard cover and 525 paper cover. Some 231 inter-library loan requests were filled in addition to personal use by Academy and library patrons. A note of appreciation was expressed to Lois for her work.

New Business

Walter Cory inquired if the Academy would co-sponsor a conference of debates sponsored by the Indiana University Conference Bureau entitled "Public Schools and the First Amendment." Discussion followed. A motion was made and then amended to read "Not to co-sponsor the conference but to indicate that we ap-

prove of the editor of the Newsletter calling attention to meetings at both the local and national level." The motion was seconded and approved.

The secretary suggested that some change in current procedures might be made to centralize the record keeping particularly of the secretary and treasurer's office. Considerable discussion ensued and a committee consisting of Robert Henderson, Duvall Jones and John Meiser was appointed to consider the total picture of procedures of operation.

The Budget Committee Meeting is set for December 5, 1981 at 10:00 a.m. at the State Library.

The Fall Meeting at the University of Notre Dame is set for October 28-30.

In final business the appropriateness of papers appearing in particular sections was discussed. It was decided that this is a prerogative of the chairman of the section. Resulting from this discussion it was decided to put interest categories on dues cards if possible.

The meeting adjourned at 10:07 p.m.

Indiana Academy of Science

GENERAL MEETING

November 6, 1981

The meeting was called to order at 1:32 p.m. by President Robert E. Henderson in Ball Theater, Humanities Center, Wabash College.

A welcome to Academy members was given by Dr. Victor Powell, Dean of the College, Wabash College.

Paul C. McKinney, Co-Chairman, Program Committee, informed the membership of various activities of the two day meeting.

The minutes of the executive committee meetings were read and approved with corrections.

The Secretary informed the membership that the list of chairmen and chairmen-elect of the sections for 1982 would be published in the Newsletter and in the minutes of this meeting. They are:

ANTHROPOLOGY

Chairman	Curtis H. Tomak
Chairman-Elect	Gary D. Ellis

BOTANY

Chairman	Kathryn J. Wilson
Chairman-Elect	L. David Polley

CELL BIOLOGY

Chairman	Douglas Duff
Chairman-Elect	Zafar Iqbal

CHEMISTRY

Chairman	Margaret A. Cavanaugh
Chairman-Elect	Eric R. Johnson

ECOLOGY

Chairman	David F. Spencer
Chairman-Elect	Richard Whitman

ENGINEERING

Chairman	Warren Williams Bowden
Chairman-Elect	David D. Chesak

ENTOMOLOGY

Chairman	Robert R. Pinger
Chairman-Elect	R. Bruce Cummings

ENVIRONMENTAL QUALITY

Chairman	Patrick J. Sullivan
Chairman-Elect	Robert H. L. Howe

GEOLOGY/GEOGRAPHY

Chairman	Akhtar H. Siddiqi
Chairman-Elect	Terry R. West

HISTORY OF SCIENCE

Chairman/-Elect	GENE KRITSKY

MICROBIOLOGY AND MOLECULAR BIOLOGY

Chairman	KEN BRUNSON
Chairman-Elect	MARY LEE RICHESON

PHYSICS AND ASTRONOMY

Chairman	ROGER ROTH
Chairman-Elect	MALCOM HULTS

PLANT TAXONOMY

Chairman	DONALD R. HENDRICKS
Chairman-Elect	JAMES R. ALDRICH

SCIENCE EDUCATION

Chairman	PATRICIA A. ZECK
Chairman-Elect	STANLEY S. SHIMER

SOIL AND ATMOSPHERIC SCIENCE

Chairman	JOHN T. SNOW
Chairman-Elect	H. RAYMOND SINCLAIR

ZOOLOGY

Chairman	DAVID M. SEVER
Chairman-Elect	RONALD L. RICHARDS

William B. Hopp, Chairman of the Nominations Committee presented the slate of candidates for office. There were no nominations from the floor. The motion to accept the candidates was moved, seconded and approved. The officers and their office for next year are:

President ..... WILLIAM R. EBERLY
Manchester College

President-Elect ..... ALICE S. BENNETT
Ball State University

Treasurer ..... DUVALL A. JONES
St. Joseph's College

Director of Public Relations ..... WALTER A. CORY, JR.
Indiana University

Academy Foundation ..... CLYDE R. METZ
Indiana University-Purdue Univ.

Bonding Committee ..... FRANK A. GUTHRIE
Rose-Hulman Institute of Tech.
JON R. HENDRIX
Ball State University

Research Grants Committee ..... JOHN H. CLEVELAND
Indiana State University

Committee Members:

DONALD J. COOK
DePauw University

J. DAN WEBSTER
Hanover College

WILLIAM B. HOPP, Chairman
Indiana State University

Richard L. Conklin presented the following names approved by the Executive Committee for election to the rank of Fellow:

BETTY D. ALLAMONG ..... Professor of Biology
Ball State University

STANLEY L. BURDEN ..... Professor and Chairman
Department of Chemistry
Taylor University

DAVID L. DILCHER ..... Professor of Paleobotany
Indiana University

THOMAS S. MCCOMISH ..... Professor of Biology
Ball State University

JACK R. MUNSEE ..... Assoc. Professor of Life Sciences
Indiana State University

CHARLES L. RHYKERD ..... Professor of Agronomy
Purdue University

ERNEST M. SHULL ..... Assoc. Professor Emeritus of Sociology
Saint Francis College

MICHAEL J. SINSKO ..... Public Health Entomologist
Indiana State Board of Health

It was moved, seconded and approved that the above individuals be made Fellows of the Indiana Academy of Science.

Fay Kenoyer Daily presented the Necrologist report for the following:

HERBERT M. CLARKE
WILLILAM DEPREZ INLOW
SCOTT MCCOY
C. MERVIN PALMER
ALBERT E. REYNOLDS
TRACY M. SONNEBORN
A. LOGAN STEELE
PAUL T. ULMAN

Howard R. Youse, Chairman of the Resolutions Committee presented the resolutions.

WHEREAS: The Indiana Academy of Science is deeply grateful to Wabash College for their invitation to hold its 97th Annual Meeting on their campus; and

WHEREAS: The administration, faculty, and students alike have cooperated in providing us their facilities for this meeting; be it

RESOLVED: That the Academy members here assembled express their sincere appreciation to President Dr. Louis S. Salter for all the courtesies Wabash College has extended to the Academy during the meeting. We are especially grateful to Dr. Paul C. McKinney and Dr. Robert L. Henry and their entire Committee for the arrangements of the entire program and the comfort and conveniences provided the membership. We also express our sincere thanks to James M. Shuler and other members of the Symposium panel for the informative Symposium on "Chemical Risk and Waste Disposal."

The resolution was moved, seconded and approved.

President Henderson praised the committee for its selection of the "Speaker of the Year" Dr. A. Alan B. Pritsker.

The meeting was adjourned at 2:20 p.m.

Respectfully submitted

John H. Meiser
Secretary

Indiana Academy of Science
FINANCIAL REPORT
For Year Ending December 31, 1981

I. ACADEMY ACCOUNTS

	Income	Budgeted	Expenditures	Budgeted
Dues	$ 8,102.00	$ 7,500.00	$ —	$ —
Reprints	790.44	4,000.00	0.00	3,500.00
Interest	1,891.17	1,200.00	—	—
Miscellaneous	319.23	0.00	—	—
Transfer from Administered Accounts	1,200.00	1,200.00	—	—
Secretary	—	—	478.67	500.00
Treasurer	—	—	407.07	400.00
General Office	—	—	169.14	350.00
Officer Travel	—	—	175.00	225.00
Membership	—	—	0.00	250.00
President's Contingency Fund	—	—	0.00	150.00
Newsletter	—	—	650.00	650.00
Speaker of Year	—	—	700.00	700.00
Program Committee	—	—	1,919.68	1,700.00
Editor *Proceedings*	—	—	900.00	900.00
Youth Activities	—	—	0.00	250.00
Biological Survey Committee	—	—	0.00	2,250.00
AAAS Representative	—	—	0.00	0.00
Public Relations	—	—	200.00	100.00
Section Chairman Expenses	—	—	50.00	50.00
CPA Fees	—	—	740.00	750.00
Lawyer Fees	—	—	0.00	100.00
Miscellaneous	—	—	0.00	100.00
	$12,302.84	$13,900.00	$ 6,389.56	$12,925.00

II. ADMINISTERED ACCOUNTS

	Jan. 1, 1981 Balance	Income For 1981	Expenditures For 1981	Dec. 31, 1981 Balance
Junior Academy	$ 1,754.01	$ 0.00	$ 523.35	$ 1,230.66
Science Talent Search	797.79	2,596.00	3,098.36	295.43
Science and Society	3,061.49	0.00	1,613.60	1,447.89
Research Grants	-6,337.68	9,443.17	9,437.00	-6,331.51
Lilly Library Fund III	2,632.76	0.00	0.00	2,632.76
Lilly Library Fund V	4,500.20	0.00	0.00	4,500.20
J.S. Wright Library Fund	134.28	0.00	0.00	134.28
Natural Areas	0.00	0.00	0.00	0.00
Library Binding	1,482.60	1,500.00	1,780.05	1,202.55
Proceedings: Publication and Sale	3,232.89	329.00	2,000.00	1,561.89
Proceedings: Mailing	522.75	300.00	0.00	822.75
Publications: Monographs Publication and Sale	2,870.02	70.71	594.53	2,346.20
Department Interior Grant 14-16-0003-79-133	404.64	1,000.00	2,000.00	-595.36
	$15,055.75	$15,238.88	$21,046.89	$ 9,247.74

III. SUMMARY

	Academy Accounts	Administered Accounts	Total
Balance as of Jan. 1, 1981	$ 3,127.80	$15,055.75	$18,183.55
Income 1981	12,302.84	15,238.88	27,541.72
Expenditures 1981	6,389.56	21,046.89	27,436.45
Balance as of Dec. 31, 1981	9,041.08	9,247.74	18,288.82

IV. BANK BALANCE AS OF DEC. 31, 1981

Checking Account	$ 2,053.15
First Citizens Bank and Trust Co.	
Saving Accounts:	
C.D. 6 mos., First Citizens Bank	10,875.83
First Western Savings	5,359.84
	$18,288.82

V. SUMMARY OF TRUST FUNDS

		Cash Balance	Carrying Value Investments
A.	Foundation Account (00430-00-0)		
	Income Account		
	Jan. 1, 1981	$ 0.00	$ 0.00
	Dec. 31, 1981	0.00	0.00
		$ 0.00	$ 0.00
	Principal Account		
	Jan. 1, 1981	$ 53.40	$ 27,158.06
	Dec. 31, 1981	1,028.60	29,158.06
		$ 975.20	$ 2,000.00
B.	J.S. Wright Fund (00430-01-9)		
	Income Account		
	Jan. 1, 1981	$4,576.83	$ 0.00
	Dec. 31, 1981	5,720.36	0.00
		$1,143.53	$ 0.00
	Principal Account		
	Jan. 1, 1981	$ 754.03	$320,017.47
	Dec. 31, 1981	112.15	316,623.29
C.	IAS Invested Income Account (00430-02-08)	$-641.88	$-3,394.18
	Income Account		
	Jan. 1, 1981	$ 1,501.23	$ 0.00
	Dec. 31, 1981	2,268.75	0.00
		$ 767.52	$ 0.00
	Principal Account		
	Jan. 1, 1981	$ 991.63	$ 53,988.60
	Dec. 31, 1981	1,102.10	81,988.60
		$ 110.47	$ 28,000.00
D.	Summary of Trust Accounts		
	Jan. 1, 1981	$ 7,877.12	$401,164.13
	Dec. 31, 1981	10,231.96	427,769.95
		$ 2,354.84	$ 26,605.82

VI. NOTES

Membership for 1981:

1,016 active members (35 Sustaining, 557 Senior, 258 regular, 83 Student, and 83 Emeritus)
59 new members
45 members dropped or resigned

Dues Structure for 1981:

$ 2.00 for Student membership
5.00 for Regular membership
10.00 for Senior membership
25.00 for Sustaining membership
2.00 additional for Family membership
1.00 additional for initiation or reinstatement fee

Special memberships include: Life membership ($300), Corporate membership ($150-500), Institutional memberships ($50-150)

Reprints, Monographs, and *Proceedings* Sales: In 1981, sales totaled $1,190.15.

Research Grants:

A total of $9,437.00 was awarded to the following persons to support their research activities: D. Adalis (Ball State), G. Gastony (Indiana), M. Hults (Ball State), W. Jones (Purdue), W. Morgan (IUPUI), C. Nelson (Indiana), R. Pringer (Ball State), V. Riemenschneider (IUSB), R. Russo (IUPUI), E. Shull (Manchester), T. West (Purdue), H. Womack (Ball State), M. Jackson (Indiana State), E. Pilitch (Indiana), C. Tomak (Indiana Dept. of Highways), T. Beutner (Marquette High School), L. True (John Adams High School), J. Taisey (East Tipp Junior High School), M. Kelty, M. Marquard, and R. Meyer (all of East Noble High School).

VII. BUDGET FOR 1982

The following budget was approved by the Budget Committee on December 5, 1981.

Academy Accounts

Anticipated Income:	
Dues	$ 8,000.00
Interest	1,500.00
Reprints	3,500.00
	$13,000.00

Budgeted Expenditures:	
Publication charges for reprints	$ 3,000.00
Secretary	600.00
Treasurer	600.00
General Office	250.00
Officer Honorarium	150.00
Membership	200.00
President's Contingency Fund	225.00
Newsletter	750.00
Speaker of Year	700.00
Program Committee	1,900.00
AAAS Representative	100.00
Public Relations	150.00
Editor's Expense	700.00
Youth Activities	400.00
Biological Survey Committee	2,250.00
Section Chairman's Expenses	100.00
CPA	800.00
Miscellaneous	100.00
Transfer to Administered Accounts	2,700.00
	$15,675.00

Administered Accounts	Transfer from Academy Accounts
Junior Academy	$ 400.00
Science Talent Search	500.00
Library Binding	1,500.00
Proceedings: Mailing	300.00
	$ 2,700.00

Endowment Funds

Anticipated Income:	
IAS Foundation	$ 2,500.00
J.S. Wright Fund	32,000.00
Invested Income Carry-Over	81,000.00
	$115,500.00

Expenditures:	
Bank Fee	$ 3,000.00
Research Grants	15,000.00
Publication of *Proceedings* (Academy's share for 1981-82)	13,000.00
Publications: Special	5,000.00
	$36,000.00

Restricted Accounts:

Anticipated Income:

Science Talent Search from Tri Kappa	$ 2,500.00
Department Interior Grant 14-16-0003-79-133	2,698.25
	$ 5,198.25

Expenditures:

Science Talent Search	$ 2,500.00
Department Interior Grant 14-16-0003-79-133	2,698.25
	$ 5,198.25

Respectfully submitted,

John A. Ricketts, Treasurer

INDIANA JUNIOR ACADEMY OF SCIENCE

OFFICERS

President ..... Ernie Tseng, Highland High School
President-Elect ..... Jody Sibbitt, Paoli Junior-Senior High School
Secretary ..... Rich Karr, Highland High School

JUNIOR ACADEMY COUNCIL

William Fariss (Polemic, Co-Chairperson	Gavit Junior High School, Hammond
Michael Kobe (Paper Planes, Chairperson	Gavit High School, Hammond
Cheryl Mason (Polemic Co-Chairman)	Highland High School, Highland
Thomas Anderson (Junior Scientist, Co-Chairperson)	Paoli Junior-Senior High School, Paoli
Carrol Ritter (Junior Scientist, Co-Chairperson)	Paoli Junior-Senior High School, Paoli
Jane Tucker (Senior Papers, Co-Chairperson)	Saint John the Baptist, Fort Wayne
Mike Miller (Senior Papers, Co-Chairperson)	Pierce Junior High School, Merrillville
Leota Skirvin (Junior Papers, Chairperson; IJAS Co-Director	Brown County High School, Nashville
Keith Hunnings (Science Fiction, Chairperson; IJAS Co-Director)	New Haven High School, New Haven
Jerry Nisbet (Youth Council Director)	Ball State University, Muncie

PROGRAM

FORTY-NINTH ANNUAL MEETING

November 6, 1981

Wabash College, Crawfordsville, Indiana

8:30-11:00 AM	Registration, Humanities Center
9:00- 9:30 AM	Welcome by Dr. Victor Powell, Dean of the College. Introduction of Candidates and Announcements. Waugh 1
9:40-11:30 AM	Poster Session. Intramural Gymnasium
9:40-10:30 AM	Paper Planes and Mousetrap Cars. Intramural Gymnasium
9:40- AM	Junior Scientist Interviews. Coaches' Conference Room
10:00-11:30 AM	Papers Presented. Junior Division, Center 204, Senior Division Center 301
10:15-10:55 AM	Group "A" Polemic. Waugh 1
11:00-11:40 AM	Group "B" Polemic. Waugh 1
12:00- 1:00 PM	Lunch, Chadwick Court
1:30- PM	Awards Presented. Waugh 1
2:45- PM	Adjournment

ELECTED STATE OFFICERS 1982-1983

President-Elect ..... Rick Karr, Highland Senior High School
Secretary ..... Michelle Trinkle, Paoli Junior-Senior High School

CANDIDATES FOR STATE OFFICE 1982-1983

President-Elect ..... Rick Karr, Highland Senior High School
Jennifer Kucharski, Gavit Senior High School
Nanette Latchaw, East Noble High School

Secretary ..... Joseph Pawlowski, Highland Senior High School
Susan Rucinski, Gavit Senior High School
Michelle Trinkle, Paoli Junior-Senior High School

SENIOR DIVISION PAPERS

Jody Sibbitt—Paoli Junior-Senior High School
"The Quantitative Determination of the Bactericidal Action and Time Factor Involved for Penicillin V as compared to Nafcillin Sodium using Colony Count methods"

Jennifer Farr—Central Noble High School
"The Effect of Trazco B-401 on Decomposing Herbicidal Residues"

Leigh A. Langner—Highland High School
"The Cleaning and Bacteriocidal Capabilities of Selected Surface Disinfectants"

Mark Paulik—Marquette High School
"Laetrile Cancer Research Phase II: A Complete Metabolic Program including Laetrile and Selenium as a Cancer Preventive on Metastatic Lung Cancer"

Thomas Beutner—Marquette High School
"Wind Tunnel Design and Remote Piloted Testing of Experimental Aerodynamic Configurations"

Ernie Tseng—Highland High School
"Biochemical Properties of Acid Phosphatase"

Nanette Latchaw—East Noble High School
"The Mount St. Helen's Syndrome"

Jon Babcock—Paoli Junior-Senior High School
"Sulfate Concentration in Well Water in Relationship to Well Depth and Geologic Strata"

JUNIOR DIVISION PAPERS

Robert M. Beglin—Marquette High School
"Scanning Electron Microscope Studies of the Effects of Weathering on Selected Metals"

Tim Ehinger—St. John The Baptist
"The Brain Controls the Mind and Body"

Petra Fuerhaupter—Highland High School
"The Effect of Sucrose Concentration on the Pollen Germination of Amaryllis"

Eric Jensen—Marquette High School
"The Effects of Cyclic AMP, Poly A, Poly U, and Satellite DNA on Lymphocytic Leukemia"

Jennifer Jensen—Canterbury School
"The Effects of Ascorbic Acid in Regeneration in Celphad Halves of Planaria"

Elizabeth Randall—Canterbury School
"Can Gerbils be Color Conditioned?"

Anne Tseng—Highland High School
"Determination of DNA Base Composition of Bovine Liver by Thermal Denaturation"

Jeff Terry—Gavit Middle School
"Does Microwave Cooking use less Energy?"

Steve Rogers—Gavit Middle School
"Solar Efficiency"

INTERVIEWS FOR OUTSTANDING JUNIOR SCIENTIST

JUNIOR DIVISION

Ann Tseng—Highland Junior High School
Eric Jensen—Marquette Junior High School
Jennifer Jensen—Canterbury School

SCIENCE FICTION STORIES

SENIOR DIVISION

James Barsic—Marquette High School
"The Lucky Ones"

Richard Bush—Marquette High School
"The Citizen and His Magna II"

Carl Bohlin—Highland High School
"Colony 5"

Karen Deardorff—Gavit High School
"Where Has Life Gone?"

Al Valle—Gavit High School
"Matter Over Mind"

Kelly Ward—Highland High School
"Despair in Aquatos"

A. K. Seybert—Shenandoah High School
"The Flight of the Crawlers"

JUNIOR DIVISION

Robert Beglin—Marquette High School
"The Survival Test"

Lisa Burosh—Gavit Middle School
"The Black Meteors"

John Hauskins—Marquette High School
"Pulmo Sinister"

Jennifer Jensen—Canterbury School
"The Outcasts"

Angeline Kantola—Gavit Middle School
"To Save a Planet"

Lisa Parsons—Marquette High School
"Never to Return"

Jeannine Poiry—St. John the Baptist
"Working Together"

Ed Rondot—St. John the Baptist
"Atari"

Ted Smith—Canterbury School
"Airium"

OUTSTANDING SCIENTIST—SENIOR DIVISION

Thomas Beutner—Marquette High School

PAPER PRESENTERS—LIFE—SENIOR DIVISION
1st Place: Mark Paulik, Marquette High School
2nd Place: Jennifer Farr, Central Noble High School
3rd Place: Jody Sibbitt, Paoli Junior-Senior High School

PAPER PRESENTERS—PHYSICAL—SENIOR DIVISION
1st Place: Thomas Beutner, Marquette High School
2nd Place: Ernie Tseng, Highland High School
3rd Place: Nanette Latchaw, East Noble High School

SCIENCE FICTION STORIES—SENIOR DIVISION
1st Place: A. K. Seybert, Shenandoah High School
2nd Place: Al Valle, Gavit High School
3rd Place: Kelly Ward, Highland High School

POLEMICS—SENIOR DIVISION
1st Place: Brown County High School
2nd Place: Highland High School
3rd Place: Highland High School

PAPER PRESENTERS—JUNIOR DIVISION
1st Place: Petra Fuerhaupter, Highland High School
2nd Place: Steve Rogers, Gavit Middle School
3rd Place: Anne Tseng, Highland High School

SCIENCE FICTION STORIES—JUNIOR DIVISION
1st Place: Robert Beglin, Marquette High School
2nd Place: Ted Smith, Canterbury School
3rd Place: Jennifer Jensen, Canterbury School

POLEMICS—JUNIOR DIVISION
1st Place: Canterbury School
2nd Place: Marquette High School
3rd Place: Canterbury School

ACKNOWLEDGMENT

The officers, members of the Junior Academy Council and all others concerned with the program wish to thank Dr. Paul McKinney and Dr. Eliot Williams of Wabash College for their efforts on behalf of our convention. We wish to thank Dr. Phillips of the Chemistry Department for his tireless work in providing judges and giving assistance throughout the day. We appreciate very much the sincere effort expended by the students who assisted as judges.

This year the Junior Academy adced the Poster Papers on a trial basis. There was very good response indicating that they may become a permanent feature. There were seventeen clubs represented at the meeting with an attendance of over 130 students.

Biological Survey Committee Report

NEW LITERATURE AND WORKS IN PROGRESS ABOUT THE BIOTA OF INDIANA

1981 Annual Report Of The Biological Survey Committee (BSC)
Of The Indiana Academy Of Science

BSC Members For 1981:

THEODORE J. CROVELLO, Chairman, Department of Biology, University of Notre Dame, Notre Dame, Indiana 46556, Phone: (219) 239-7496, SUVON: Your access code plus 736 + 7496
JOHN A. BACONE, Indiana Department of Natural Resources
WILLIAM CRANKSHAW, Ball State University
JAMES R. GAMMON, DePauw University
JACK R. MUNSEE, Indiana State University, Terre Haute
GEORGE R. PARKER, Purdue University, West Lafayette
VICTOR RIEMENSCHNEIDER, Indiana University, South Bend
JOHN WHITAKER, JR., Indiana State University, Terre Haute
HARMON P. WEEKS, Purdue University, West Lafayette
FRANK N. YOUNG, JR., Indiana University, Bloomington

The goal of the Literature Subcommittee of the Academy's Biological Survey Committee is to accumulate and maintain published and unpublished references on the biota of the State. While in the past the BSC Literature Project has presented its findings in conventional printed form, in addition we now simultaneously add these contributions to the Indiana Academy's computerized literature and works in progress register. It provides updated, integrated bibliographies on particular topics in response to specific requests. Contact Professor Crovello for further details or to submit literature or project information to the data bank. The data bank contains more information about each reference than is presented in this printed summary. Items omitted here include: Higher taxa (common name) to which organisms belong; Classes or orders of organisms; Families; Genera or species; Subjects describing each work; and name, address and telephone number of person to contact for further information on each entry.

The following literature references and works in progress were obtained by circulating requests and questionaires to chairpersons of 69 life science departments throughout the State, and to participants at the Academy's Fall Meeting. The Committee welcomes suggestions on ways to increase the number of contributions to this annual survey, and to increase awareness of its customized computer search capabilities.

Each literature reference or work in progress given below may contain the following, separated by semicolons: author(s); date; title; citation; and Indiana counties in which the work was performed. If any of these are absent, the contributor did not provide it. Counties are abbreviated by using their first five letters. The exception is Saint Joseph, which is abbreviated StJoe.

An "ALL" in the county field indicates that the work applies to all 92 Indiana counties. A "MANY" indicates the work applies to many counties. In both cases up to five of the most important counties also may be included.

Each citation begins with a letter which has one of the following meanings:

P: Formal Publication (PIAS refers to Proceedings, Indiana Academy of Science)
I: In Press in a formal publication.
T: Thesis
O: Other (semi) published work, e.g. park checklists, maps.
E: Environmental Impact Statements
W: Work in Progress

AKRE, R. D., A. GREENE, J. F. MACDONALD, P. LANDOLT and H. G. DAVIS; 1981; The yellowjackets of America north of Mexico; P: USDA Agricultural Handbook No. 552. 101 pgs; ALL.

AWASH, T.; 1981; Effect of chemical and physical factors on the production of *Culex pipiens* in swine waste lagoons; T: Purdue University-Dr. R. E. Williams; Tippe Carro Clint.

BARSTOW, B. B.; 1981; Correlation of relative with absolute Mexican bean beetle sampling techniques; W: Purdue University-Department of Entomology; Lawre Clay Shelb Henry.

BLEDSOE, L. W.; 1981; The immature morphology and development of *Pediobius faveolatus* Crawford (Hymenoptera: Eyiophidae), an exotic, endoparasite of the Mexican Bean Beetle, *Epilachna varivestis* Mulsant (Coleoptera: Coccinellidae); T: Purdue University-Dr. C. R. Edwards.

CORRIGAN, R. M. and G. W. BENNETT; 1981; Efficacy of Rozol tracking powder on nuisance big brown bats; T: Purdue University—G. W. Bennett; Tippe Montg Shelb Hendr Boone.

DAILEY, J., J. CRAIG, K. WELBORN, and T. KOZEL; 1981; Present status of *Taxodium distichum* (L.) in Hovey Lake, Posey County, Indiana; I: PIAS: Posey.

DEYRUP, M.; 1981; Annotated list of Indiana Scolytidae (Coleoptera); P: Great Lakes Entomol. 14: 1-9; MANY.

DEYRUP, M.; 1981; A new species of *Cryptoxilos* (Hymenoptera: Braconidae) attacking adult *Lymantor decipens* LeConte (Coleoptera: Scolytidae); I: Entomol. News; Tippe.

HART J. W. and R. D. WALTZ; 1981; Studies of Indiana *Collembola*; W: John W. Hart—IU—East, Richmond, Indiana; R. D. Waltz,—Dept. Entomol., Purdue Univ., W. Lafayette; ALL.

HILL, G. D.; 1981; Identification and seasonal abundance of synanthropic flies and related manure fauna in enclosed egg-layer houses in north central Indiana; T: Purdue University—Ralph E. Williams; Carro Kosci.

JOHNSON, T. B. and F. T. TURPIN; 1981; Biological interactions between corn rootworms and foxtail species; T: Purdue University—Prof. F. T. Turpin; Tippe.

KOZEL, T. R., G. K. WEDDLE, K. L. WELBORN, J. T. DAILEY, D. C. DAILEY, and M. W. DENNER; 1981; A fish faunal survey of Posey County, Indiana; P: PIAS 90:446-453; Posey.

KREKELER, C. H.; 1981; The biota of the Indiana Dunes National Lakeshore; O: Chap. 3 of Basic Ecosystem Studies of the Indiana Dunes National Lakeshore. Submitted by School of Public and Environmental Affairs, Indiana University Northwest; Porte LaPor Lake.

MACDONALD, T. F., R. D. AKRE, and R. E. KEYEL; 1980; The German yellowjacket (*Vespula germanica*) problem in the United States (Hymenoptera: Vespidae); P: Bull. Ent. Soc. Amer. 26:436-42; MANY.

MacDonald, J. F.; R. W. Matthews; 1981; Nesting biology of the eastern yellowjacket, *Vespula maculifrons* (Hymenoptera: Vespidae); P: J. Kans. Ent. Soc. 54:433-457; MANY.

MacDonald, J. F. and R. W. Matthews; 1982; Nesting biology of the southern yellowjacket, *Vespula squamosa* (Hymenoptera: Vespidae); W: Dept. Entomology—Purdue University; Tippe Clark.

MacDonald, J. F., R. W. Matthews, R. S. Jacobson; 1980; Nesting biology of the yellowjacket, *Vespula flavopilosa* (Hymenoptera: Vespidae); P: J. Kan Ent. Soc. 53:448-458; MANY.

McCain, J. W.; 1982; Checklists of the vascular plants of Tippecanoe and Kosciusko Counties, Indiana; W: Purdue University—Botany Dept.; Tippe Kosci.

McCain, J. W. and J. F. Hennen; 1981; Notes on biogeography and new records of rust fungi in the Great Lakes region; I: PIAS; MANY.

Meyer, R. W.; 1981; Insects and other arthropods of economic importance in Indiana in 1981; I: PIAS; MANY.

Minton, S. A.; 1980; Butler's garter snake; P: Cat. Amer. Amphib. and Reptiles 258:1-2; MANY.

Orpurt, P. A.; 1981; The Gasteromycetes of Indiana; I: PIAS; ALL.

Orpurt, P. A.; 1981; *Conium maculatum* L. in Indiana; I: PIAS; MANY.

Orpurt, P. A.; 1981; The Umbelliferae of Indiana; W: Manchester College—Biology Dept.; ALL.

Provonsha, A. V. and W. P. McCafferty; 1982; New species and previously undescribed larvae of North American Ephemeroptera; I: Journal of the Kans. Entom. Soc.; MANY.

Riemenschneider, V. L. and T. Blodget; 1981; Post wind damage survey of Bendix Woods Nature Preserve, an old growth beech-maple forest in St. Joseph County, Indiana; W: Indiana University at South Bend—Biology Dept; StJoe.

Schall, R. A.; J. W. McCain, J. F. Hennen; 1982; Distribution and phenology of rust fungi on corn in Indiana; W: Purdue University, Botany Dept.,—J.W. McCain; ALL.

Senft, II, W. H., R. A. Hunchberger and K. E. Roberts; 1981; Temperature dependence of growth and phosphorus uptake in two species of *Volvox* (Volvocales: Chlorophyta); I: J. Phycology 17(4); Delaw.

Shipman, S.; 1982; Centrarchid population dynamics in two small northeast Indiana lakes; W: Indiana Dept. of Natural Resources—Div. of Fish and Wildlife; Noble.

Sisco, R. and F. T. Turpin; 1981; The role of the crop consultant in the implementation of rest management in corn, soybeans and alfalfa in Indiana; W: Purdue University, Dept. of Entomology—Tom Turpin; MANY.

Smith, B. and R. Inouye; 1981; Wasp gall distribution and dynamics on *Quercus alba*; W: Earlham College; Wayne.

Thomas, A. K., R. R. Pinger, P. R. Grimstad; 1981; Confirmation of a LaCrosse Virus isolate in Northern Delaware County, Indiana; I: PIAS (Abstract); Delaw.

Waltz, R. D. and W. P. McCafferty; 1982; Caddisflies of Indiana; T: Purdue University—Dr. Pat McCafferty; ALL.

Yoder, L.; 1982; Vascular flora of the Merry Lea Nature Preserve; W: Goshen College—Biology Dept.; Noble.

Yonker, J. W.; 1981; Selected aspects of the biology, behavior, damage and control of the Zimmerman pine moth *Dioryctria zimmermani* in Indiana; T: Purdue University, Entomology—Dr. D. L. Shuder; MANY.

Necrology

Fay Kenoyer Daily, Butler University

HERBERT M(ORRIS) CLARKE

Near Rensselaer, Indiana — Middleton, Wisconsin
December 15, 1909 — April 22, 1981

Dr. Herbert M. Clarke was Professor Emeritus of the University of Wisconsin, Madison, when he died April 22, 1981, in his home at Middleton where he had lived since 1946.

Dr. Clarke was a native of Indiana having been born near Rensselaer on December 15, 1909. He also resided in Franklin, Indiana, and received an A.B. degree from Franklin College in 1931. He completed graduate work at the University of Wisconsin receiving an M.S. degree in 1933 and a Ph.D. degreee in Botany in 1935.

After graduation, he went to teach at Bacone Junior College, Muskogee, Oklahoma, from 1935 to 1942. However, he served in the U.S. Medical Corps from 1942 to 1945 progressing from Private to First Lieutenant. In 1946, he began teaching at the University of Wisconsin where he remained until retirement in 1974. He served many years as Dean of the College of Letters and Science beginning in 1958.

Dr. Clarke joined the Indiana Academy of Science in 1929 when still an undergraduate at Franklin College. He became an Emeritus Member in 1975, the year that he retired. He was a member 52 years even though he was out-of-state since 1931. He was also a member of the Botanical Society of America, Sigma Xi, American Fern Society, Wisconsin Academy of Science, Lambda Chi Alpha, and the Christian Church.

His research interests centered, primarily, on pteridophyte morphology, morphology and anatomy of *Lygodium Japonicum*, comparative anatomy of Lycopodium and a gymnosperm bibliography. He is listed in *American Men of Science* and *Who's Who in the Midwest* and is in *Indiana Scientists* by S.S. Visher.

Dr. Clarke served our society as a loyal member supporting it for a great many years. We are fortunate for such a long-time member.

WILLIAM DEPREZ INLOW

Manilla, Indiana
November 27, 1890

Shelbyville, Indiana
February 11, 1981

Dr. William De Prez Inlow was a retired surgeon and writer who died at Shelbyville, Indiana, February 11, 1981. He was a native of Manilla, Indiana, where he was born November 27, 1890. He graduated from high school at Shelbyville in 1909. He attended Indiana University from 1910 to 1912 and then received a B.S. degree in 1915 and Master of Science degree in 1917 from the University of Chicago. He also received a Doctor of Medicine degree from Rush Medical College in 1917. His internship was served at Cook County Hospital in Chicago, but was interrupted by service as an officer in the Army Medical Corps at Camp Meade, Maryland, during World War I. After completing his internship, he received a fellowship (1919-1923) in surgery at the Mayo Clinic. He also spent a year of study in Vienna and Paris.

Dr. Inlow's professional career began with teaching and the principalship of Homer High School lasting 2 years before studying medicine. After medical training in 1923, he formed the Inlow Clinic at Shelbyville with his brothers, Dr. H.H. Inlow, a roentgenologist, and Dr. Fred Inlow, a urologist. He established the Inlow Clinic Library and was President of the Inlow Foundation. He was active in practice there until he retired at 70 years of age.

Dr. Inlow's retirement saw the beginning of a new career for him in writing (*Indianapolis Star*, November 28, 1960). He was interested in the history of Science and Anthropology which led to a paper, The *Indiana Physician as Geologist and Naturalist* which was presented at an annual meeting of the Indiana Academy of Science in 1950, the year he joined the society. He also had used this subject in an address before the Indiana Association of the History of Medicine at a preconference meeting at the Indiana State Library December 11, 1947. The writing was finished and the subject was the title of an interesting paper published in 1960, in the *Indiana Magazine of History* LVI (1); 1-35. In it, several of our charter members were mentioned: Richard Owen, R.T. Brown, Amos Butler, E.R. Quick, A.J. Phinney, John M. Coulter, John N. Hurty, Alembert W. Brayton, Fred Stein, Fletcher M. Noe, Oliver P. Hay, Maurice Thompson, and David Starr Jordan. A few members who joined the Academy later were also mentioned. Dr. Inlow became an Emeritus Member of our society.

Other societies with which Dr. Inlow was affiliated were: Phi Chi Medical Fraternity, American Association for the Advancement of Science, American Association of the History of Medicine, Shelby County Historical Society, Indiana Historical Society, American Medical Association (Shelby County, state and national branches), Past Delegate of the Indiana State Medical Association and Past Chairman of the Surgery Section of that society, Phi Beta Kappa and Sigma Xi.

Dr. Inlow was 90 years old when he died February 11, 1981, in the W.S. Major Hospital where he had been a member of the W.S. Major Hospital Foundation. He lived a long and fruitful life.

SCOTT MCCOY

Emison, Indiana — Indianapolis, Indiana
May 25, 1897 — December 26, 1980

Mr. Scott McCoy was a retired botany teacher and park botanist and superintendant, who died December 26, 1980, in Indianapolis, Indiana. He was born May 25, 1897, on a farm in Knox County, Indiana, near Emison. He attended grade and high schools in Emison and entered college at Indiana University in 1916. He was captain of the freshman track team and cross country runners. His training there lasted a year when he entered the navy during World War I. He served on an anti-submarine crew on the U.S.S. Louisiana which was on convoy duty in the Atlantic.

He did not return to school after the war, but sought employment at Indiana Bell Telephone Company in Vincennes. He became chief clerk in the office in 1926. He was assistant secretary at the Indianapolis Morris Plan Company later.

In 1927, he joined the Nature Study Club and in 1928 joined the Indiana Academy of Science; so his interest in natural history was well nurtured. Under the influence of Dr. Ray C. Friesner, he entered Butler University in 1934, receiving a B.S. degree in 1937 and an M.S. degree in 1938.

Mr. McCoy's new career began at Arsenal Technical High School as a teacher of botany and landscaping in 1937 where he taught 30 years. Summers found him with a group of students maintaining beautiful gardens and lawns around the city. This was a fine opportunity for students to make some money, receive on-the-job training and obtain a one-on-one personal relationship with the teacher, too. Mr. McCoy developed a nature preserve and botanical garden on the Tech High School grounds. He had charge of the herbarium and botanical garden at Butler University, too, and taught courses in summer school there. His appointment as botanist at the John H. Holliday Park and botanical garden came June 17, 1941, by the Superintendant of Parks of Indianapolis, A.C. Sallee. He resigned in 1947 because of differences with Paul V. Brown, city parks director, whom he charged with non-support of his efforts to upgrade and maintain the park. He was a forester at the Eagle Creek Reservoir, and was interested in planting different species of native plants there as well as carrying on the usual forestry duties.

After retirement in 1967, Scott McCoy continued his interest in higher plant taxonomy and shells. He arranged his specimens, collected more, grew a large garden and cared for a large tract of land around his home.

Mr. McCoy joined the Indiana Academy of Science in 1928, as mentioned earlier, and was honored as Fellow in 1947. His first paper given before the society was on his ecological survey of plants on the Guthrie Estate in Jennings County which the Nature Study Club had recently acquired. This study and a much larger one including 25 tracts of the Illinoian Till Plain was the basis for his Master's thesis completed in 1938. A paper based on this study was presented also to the Academy. A number of other studies including one on a new species of honey locust were given before our society. He also belonged to the Masonic Lodge (Past Master in the Blue Lodge Chapter and Council). He was generous with time and energies to help others and share his knowledge of plants which was considerable after close association with C.C. Deam, R.C. Friesner, and other eminent Academy plant taxonomists. He died of a heart attack at St. Vincent's Hospital at the advanced age of 87.

C(HARLES) MERVIN PALMER

Chester, Pennsylvania
August 25, 1900

Kennett Square, Pennsylvania
March 16, 1981

Dr. Charles Mervin Palmer was born at Chester, Pennsylvania, August 25, 1900, and was raised and educated there during grade and high school. He had a natural interest in sciences and botany in which he majored at Pennsylvania State College where he received a B.S. degree in 1922 and M.S. degree in 1925. He was assistant in Botany there from 1922 to 1924 and instructor from 1924 to 1925.

In 1925, Dr. Palmer came to Indiana to teach Botany at Butler University. He taught there for 25 years developing several courses in Bacteriology, Phycology and Applied Microscopy. His chief research during this period was a continuation of studies on Lemanea and Sacheria which were begun in pursuit of his Ph.D. degree. He started an algal distribution file system at Butler based on published listing. The Indiana file is still maintained by W.A. and F.K. Daily at Butler, and it has been computerized by Ted Crovello.

In 1950, Dr. Palmer left Butler to become head of the nuisance organisms unit in the biological section of the Robert A. Taft Sanitary Engineering Center, U.S. Public Health Service at Cincinnati. He studied interference organisms, pollution and the quality of water supplies. He developed a standard of water quality based on nuisance organism indicators which is widely used by the Environmental Protection Agency and others. He received a Superior Service Award from the U.S. Department of Health, Education and Welfare in 1956 for his excellent work. A booklet, *Algae in Water Supplies*, was prepared by Dr. Palmer and the algae were beautifully illustrated by Harold J. Walter under Dr. Palmer's direction. This was published in 1959 by the U.S. Government Printing Office (Public Health Service Publication No. 657). This grew from an earlier publication on the subject by Dr. Palmer in *Public Works* (86:107-120. June, 1955). About 50,000 copies of the 1959 booklet were printed in 8 printings. A Spanish edition was printed in Mexico and distributed throughout Latin America with a special bibliography in 5 languages. It also was translated into Japanese. The color plates were included in editions of *Standard Methods of Examination of Water and Wastewater* by the American Public Health Association, American Water Works Association and the Water Pollution Control Federation. The plates were enlarged and distributed by the U.S. environmental Protection Agency.

Dr. Palmer and his wife participated in many Quaker activities. He was unit leader of the Friend's Service Unit in India and Pakistan from 1947 to 1948. His wife, Esther, was in charge of the Friend's International Center in Calcutta. This was a time of great hardship and turmoil in these countries related to partitioning. Dr. Palmer made significant contributions to improving agricultural methods there and met many plant scientists in education and research institutions. His wife served the needs of displaced persons. Two papers based on these experiences were given at Academy meetings. He was Director of Civilian Service Camp No. 12, New York, in 1941; field officer for a scientific co-op office for South Asia for UNESCO from 1948 to 1949; and consultant for the International Co-op Administration, Brazil, from 1959 to 1960.

Dr. Palmer joined the Indiana Academy of Science in 1925, the year he came to teach at Butler. He was made Fellow in 1929. He served on the Biological Survey Committee from 1934 to 1947, was Press Secretary from 1942 to 1947, Chairman of

the Bacteriology Section in 1945, and Chairman of the Invitations Committee in 1945. He gave many papers on the check-list of Indiana algae, new and unusual algae in Indiana, a history of Bacteriology at Butler University, and a key to the genus Bacillus. Some of the last papers were on the algae of waste stabilization ponds.

Dr. Palmer was affiliated also with the American Institute of Biological Science, Botanical Society of America, Society of Limnology and Oceanography, Phycological Society of America (charter member and vice-president in 1953), and Microscopic Society of America.

After retirement, Dr. Palmer moved to Kennett Square, Pennsylvania (early 1970s). He wrote another booklet, *Algae and Water Pollution*, which was a revision and enlargement of his earlier booklet and with the emphasis on water pollution and the associated algae. This one incorporated the color plates by Walter and added two more by Sharon Adams. It was published in 1977. He also pursued algal study at the Academy of Natural Sciences at Philadelphia. Many collections were distributed by him. Some were sent to his good friends, Carlos and Rosa Maria Bicudo at the Instituto de Botanica, Sao Paulo, Brasil, where he spent six months on a teaching assignment. Other specimens were sent (after death) to the Academy of Natural Sciences of Philadelphia.

Dr. Palmer died March 16, 1981, at the retirement home in Kennett Square, Pennsylvania, where he lived. He had been a successful teacher, effective research director, and kind and helpful friend.

ALBERT E(UGENE) REYNOLDS

Staunton, Indiana
August 4, 1907

Indianapolis, Indiana
May 24, 1981

Dr. Albert E. Reynolds taught 50 years at DePauw University. His research centered, primarily, on the general biology of lizards, salamanders and skinks.

Dr. Reynolds was born at Staunton, Indiana, August 4, 1907, and he was educated in the state receiving an A.B. degree from DePauw in 1930.

DePauw hired Dr. Reynolds after graduation to become an assistant in Zoology from 1930 to 1932. At that time, he became an instructor. In 1935, he obtained an M.S. degree at Chicago and in 1941 a Ph.D. degree from the same university. Apparently, some leave of absence from DePauw was obtained to satisfy requirements at Chicago University for these degrees, but teaching at DePauw is given as continuous in biographical accounts through these years. From 1932 to 1947, he was an instructor and a professor from 1947 to 1973. he served as head of the Zoology Department from 1961 to 1973 when he retired. He became Emeritus Professor at that time, but continued teaching until 1980 which made 50 years of teaching at DePauw.

Dr. Reynolds had a full life. In addition to the time taken for advanced degrees, he served in the U.S. Air Force during World War II, and was connected with high altitude physiology at Randolph Field and aviation medicine at Cochran Field. He was Lieutenant Colonel in the U.S. Air Force Reserve at the time of death. He was also an instructor in the school of nursing, Methodist Hospital, Indianapolis, from 1950 to 1965.

Dr. Reynolds became a member of the Indiana Academy of Science in 1929 and a Fellow in 1964. He was a senior member at death. He presented over a dozen papers over a thirty-year period, chiefly on amphibians and reptiles, but covering a few other subjects such as the evidence of a mastodon in Hendricks County. He was chairman of the Zoology Section in 1947 and was author and co-author of two papers given in the section that year. He was a recipient of a research grant from our society the next year, 1948. He was a member 52 years.

In addition to the Indiana Academy of Science, Dr. Reynolds was a member of several other professional societies: the Society for the study of Amphibians and Reptiles, American Society of Zoologists, Society for the Study of Evolution, and Sigma Xi. He served the Gobin Memorial United Methodist Church from lay leader to being a member of the Board of Trustees and had been a delegate to the annual conference. He belonged also to the Alpha Tau Omega fraternity, Greencastle Kiwanis Club, Huttle Club and Putnam County Historical Society for which he served as program chairman. He was an adult leader also in the Boy Scouts and was honored with the Silver Beaver Award.

Dr. Reynolds was highly regarded at DePauw University and was considered a prominent educator. A scholarship fund in his honor has been established there since his death on May 24, 1981. His last days were spent in the Lilly Research Hospital, Indianapolis, where he was a patient for three months before death. Our society was very fortunate to have the 52-year support from this fine man.

TRACY MORTON SONNEBORN

Baltimore, Maryland
October 19, 1905

Bloomington, Indiana
January 26, 1981

Dr. Tracy M. Sonneborn had been an internationally known geneticist and Distinguished Service Professor of Zoology at Indiana University, Bloomington Campus, and was Emeritus Professor at death in Bloomington on January 26, 1981.

Dr. Sonneborn was born in Baltimore, Maryland, October 19, 1905, and was educated at Johns Hopkins University receiving a B.A. degree in 1925 and a Ph.D. degree in 1928. He was a National Research Fellow at Johns Hopkins from 1928 to 1930, assistant in Zoology from 1930 to 1931, a research associate in Zoology from 1931 to 1933, and an associate professor from 1933 to 1939.

In 1939, Dr. Sonneborn came to Indiana University at Bloomington. He moved from associate professor to professor in 1953 when he was honored as Distinguished Service Professor. In 1976, at retirement, he became Emeritus Professor. He had several concurrent positions: visiting professor and honorary member of the faculty of biology and medical science at the University of Chile in 1951, special lecturer at the University College of London in 1955, Vanuxem lecturer at Princeton University in 1960, and Pasteur lecturer at Georgetown University in 1964.

Dr. Sonneborn's talents were many and widely recognized and rewarded. *Your University* published by Indiana University (V. 18, No. 5, September, 1964) reflected on his career there. The title of the article was *Distinguished Teaching and Research Marked his Career at Indiana University*. In it, he was characterized as an outstanding teacher, patient, brilliant researcher with an unusual ability to understand and inspire students and to impart to them an appreciation of nature and the excitement of the process of discovery. His research resulted in about 175 publications and was supported by grants from the Rockefeller Foundation, Atomic Energy Commission and American Cancer Society.

Several honors were awarded to him as time passed. In 1942, he was made a member of the American Philosophical Society, an old and distinguished learned society.

After many years of research on Paramecium, Dr. Sonneborn found that rather than sexless mating behavior that had been ascribed to the genus, there were distinct mating types. This opened up a whole new field for experimentation and under Dr. Sonneborn's direction, different strains were cross-bred. That led to the finding that contrary to the usually held belief that genes are found only in the nucleus, there were determinants in the cytoplasm termed "plasma-genes". These were found to hold control over inheritance of so-called "killer" types which produced a substance which killed other paramecia. For this basic and classic study, Dr. Sonneborn was the recipient of the American Association for the Advancement of Science Research Award in 1947. His chief assistants were Winifred Jacobsen and Ruth Dippell.

Dr. Soneborn also observed that paramecia in aging developed defective chromosomes. He concluded that, possibly, human aging might be marked by similar chromosome changes. This was verified by later research in this field.

In 1955, a symposium of the American Association for the Advancement of Science was held in Atlanta. An announcement of the Symposium Volume, No. 50,

October, 1957, stated that Dr. Sonneborn's comprehensive survey of species problems in protozoans and, particularly, the ciliates comprised a masterly thesis of about two-fifths of the volume. It was a fundamental contribution to protozoan literature.

In 1959, the National Academy of Science met at Indiana University on April 27 when Dr. Sonneborn received the Kimber Award, the highest honor in America for genetics research. This award carried a gold medal and $2,000 in cash. The National Academy met at Indiana University again that fall, November 16 to 18. It was announced that one of the highlights of the meeting would be the lecture on *The Gene and Cell Differentiation* by the "prize winning zoologist, Tracy Sonneborn".

In 1964, he was honored by the British when elected to the British Royal Society. He was also a member of the American National Academy Public Policy Committee that year. At the annual meeting of the National Academy of Science, he announced that "genes may be able to make viruses", and pointed out that this may open new doors in cell and cancer research. There has been much attention to this field since then with the knowledge that a better understanding of the virus-host cell relationship might hold the key to a better understanding of viral related types of cancer.

In other honors, he received the Frederic Bachman Lieber Award in 1967 for Distinguished Teaching; a medal from the Czechoslovak Academy of Science; and he was made chairman of a conference in Washington, D.C., December, 1970, at which genetic surgery was discussed and methods given for reverse transcription of genes.

Dr. Sonneborn became a member of the Indiana Academy of Science in 1940 and a Fellow in 1953, and was an Emeritus Member at death. His studies of *Paramecium aurelia* were the subject of several papers presented at Indiana Academy of Science meetings and he was chairman of the Zoology Section in 1942. He presented a paper at that meeting on *Acquired immunity to a specific antibody and its inheritance in Paramecium aurelia.* In addition to our society, he supported the American Association for the Advancement of Science, American Society of Naturalists (treas. 1944 to 1947; vice president, 1948; president, 1949), Genetics Society of America (president, 1949), American Society of Zoology (president, 1956), National Academy of Science, American Philosophical Society, American Society of Arts and Sciences, and Harvey Society. He served on the editorial board of the *Journal of Morphology, Genetics, Journal of Experimental Zoology, Physiological Zoology,* and *Annual Revue of Microbiology.*

He has been the subject of numerous articles in newspapers and biographies can be found in *American Men and Women of Science, Who's Who in Indiana,* and *Indiana Scientists.*

These many accomplishments are truly exceptional.

A. LOGAN STEELE

West Lafayette, Indiana
April 8, 1910

Crown Point, Indiana
May 30, 1979

Mr. A. Logan Steele was a Hoosier born April 8, 1910. His career rested chiefly with Indiana Bell Telephone Company as an executive, but he was also a high school teacher and college professor.

Mr. Steele began his education at West Lafayette and graduated from Jefferson High School in 1926. He then earned an A.B. degree at Wabash College in 1929 where he majored in Psychology. He majored in English at the University of Texas where he received an M.A. degree in 1936.

His career with Indiana Bell Telephone Company started as assistant traffic supervisor in Indianapolis, 1929. During the 1930s, however, he took his recent bride to Texas where he taught in a junior high school. He came back to Indiana after three years of teaching to be an assistant supervisor at Indiana Bell Telephone Company in Muncie. After three more moves, he returned to Indianapolis for Indiana Bell. He also taught at Indiana University-Purdue University at Indianapolis one night a week. He was appointed editor of the company's first employee newspaper, *Highlights*, in 1950. He had a journalistic background in college where he was editor of two publications. Besides serving in the above assignments at Indiana Bell Telephone Company, he was in public relations, connecting company relations and a personnel supervisor prior to retirement. He retired in 1973 after 41 years of service to the company.

At that time, Mr. Steele became Assistant Professor of Technology, Division of General and Technical Studies at Indiana University Northwest at Gary, Indiana. In October, 1975, he became also Coordinator of Operations Supervision Technology and Acting Chairman of the Division holding the appointment until 1976. He resigned because of ill health in May, 1977.

At retirement from Indiana Bell in 1973, Mr. Steele was Secretary-Treasurer for the Hoosier State Chapter 16 of the Telephone Pioneers of America which position he held from 1962. During this service of 11 years, he had established the professional publication, the *Hoosier Pioneer* for the society. The July 1979, issue (No. 195) has a nice article and pictures of Mr. Steele in it. This was kindly provided for us by the present editor and author of the article, Sandi Stepp. The Pioneers are dedicated to both social activities and community service.

Mr. Steele joined the Indiana Academy of Science in 1964. He was living at that time at Leroy, Indiana. He was a family member with his wife, Joan, who has an interest in Anthropology. He also belonged to Phi Beta Kappa and Pi Delta Epsilon.

A pulmonary embolism due to lung cancer took Mr. Steele's life May 30, 1979, at Crown Point, Indiana. Miss Sandi Stepp finished her article about Mr. Steele with, "His efforts in pioneering will long be remembered." Considering the accounts of volunteer activities in the publication—his contributions to such an organization are very praiseworthy.

PAUL T. ULMAN

Spring Mountain, Ohio
August 13, 1893

Noblesville, Indiana
November 22, 1980

Mr. Paul T. Ulman was born at Spring Mountain, Ohio, August 13, 1893. His higher education was received from Washington State College, and he came to Indiana to work in the State Entomologist's Office before World War I.

During the war, he served with the 113th Engineers, American Expeditionary forces in France attaining the rank of Staff Sergeant. Upon return, he worked with the Michigan Department of Agriculture.

It was 1926 when Mr. Ulman came back to Indiana to be in charge of the European Corn Borer Laboratory near Auburn when it was established. It was back to Indianapolis in 1933. At the Division of Entomology, Indiana Department of Conservation, he was in charge of pest control and nursery inspection.

Mr. Ulman joined the Indiana Academy of Science in 1931, and was active in the Entomology Division. In 1939, he was chairman of the Entomologists informal Saturday meeting held after our annual fall meeting on Friday at the Indiana State Teacher's College. In 1953 and 1954, he was chairman of the Entomology Division and participated (1954) in a special symposium moderated by Ray T. Everly in conjunction with the celebration by United States entomologists in recognition of the 100th anniversary of economic entomology as a profession in this country. Mr. Ulman spoke on *Regulatory Entomology in Indiana.*

Mr. Ulman was also active in several other societies and helped found the Indiana State Gladiolus Society in 1929 which he served for over 40 years. Also, he founded and was past president of the North American Gladiolus Council. He was a member of the Entomological Society of America, honorary member of the Indiana Nurseryman's Association and Blatchley Nature Study Club. He was secretary-treasurer of the Central Plant Board 1931 to 1941 and contributed significantly until retirement in 1959.

Mr. John J. Favinger, Indiana State Entomologist, shared with us a fine obituary that he wrote about Mr. Ulman, much of which has been incorporated here. He characterized Mr. Ulman as follows: . . . "He . . . was nationally recognized as an expert in the commercial production of gladiolus. . . . An expert photographer in his early professional career, he made a number of plates illustrating Charles C. Deam's classic *Trees of Indiana.* . . . An exacting supervisor, he had the affection and respect of those of us he trained, maintaining an avid interest in plant regulatory problems during my last visit with him a few weeks before his death."

Mr. Ulman died November 22, 1980, at Noblesville, Indiana at a local nursing home. He had been a resident of Noblesville for 44 years, and and was 87 years old.

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ADDRESSES AND CONTRIBUTED PAPERS

THE ENERGY FUTURE FOR INDIANA

ROBERT E. HENDERSON
Indianapolis Center for Advanced Research

Introduction

There are several reasons for selecting this topic for the address to the Indiana Academy of Science in 1981. Most energy studies are federal and international in nature. I believe that it is important to take a look at the regional and local aspects of energy futures. The energy picture, although still highly volatile, has stabilized somewhat in the last six years so that a prediction of the future can be related now to certain assumptions and objectives with a degree of clarity that might not have been possible in the mid 70s. Furthermore, there is a great deal in the way of self-fulfilling prophecy in the prediction of futures. I believe that various approaches to energy in the state will be affected by the predictions that are made. I am proposing a general approach which I believe is not only possible, but would be good for the state to undertake in terms of its economic development and its employment situation. Therefore, the possibility of this and many other presentations having some effect on the outcome is one reason for undertaking this topic.

Hypotheses for Prediction

There are four major hypotheses behind these predictions for Indiana. First, the interdependence in energy-related affairs will not go away. For instance, for many years in the 1960s, there was an assumption on the part of automobile companies, based on input from energy companies, that stable oil availability and pricing would continue well into the end of the 20th century as it had been in the post Second World War time period. It was this assumption, not mistakes in engineering, which caused problems with respect to the marketing and, therefore, the production of cars that today are not as competitive in world markets as they might be. Another clear case of interdependence is our dependence upon a continuing relatively peaceful situation in the Middle East—peaceful enough, that is, for the supplies of oil from that region to the United States to continue. Thus, the Department of Defense actions, insofar as they maintain peace in the Middle East, are more important to the future of energy than those of the Department of Energy.

Another demonstration of interdependence is the question of the relationship between energy and inflation. The effects of energy supply on inflation lead to political decisions. The best example is the long term suppression of natural gas prices because of control by the government; leading to the reduction in new supplies of natural gas and its relative scarcity. Although arguments can be presented on both sides, there is this interdependence of various actions taken by the government that relates energy predictions to political, social, and economic activities both in the United States and abroad.

In summarizing this interdependence hypothesis, futures with respect to energy are far more dependent upon political, social, and economic factors than they are on specific technical expertise. This is an extremely important relationship for scientists and engineers to understand in order for their efforts to be effec-

tive. Most scientists and engineers recognize that there is a great deal that they can contribute to energy futures from the standpoint of increasing energy resources, bringing in alternative resources, and developing energy conservation schemes. These developments by scientists and engineers are not now and will not be in the next 20 years the driving factor for determining energy production and consumption.

The second hypothesis behind these predictions is that we are not faced with a major shortage of energy at the present time and will not be in the next 20 years. There may be cost and availability problems in bringing those resources to a proper application—whether they be resources in solar, fossil fuels, nuclear, or others. However, in our lifetimes and well into the 21st century, we are not faced with an actual shortage of energy. Many speakers on behalf of nuclear and solar energy, for instance, talk about the infinite supply that can be gained from solar energy systems or nuclear breeder reactors. Those claims, of course, do not mean very much until they are brought into actual operation. Thus, the second assumption is that there is plenty of energy for the foreseeable future.

The third hypothesis is that because of cost and availability situations, conservation and efficiency considerations relating to energy development will become more and more important in years to come. Out of this background assumption comes a very interesting conclusion which I will attempt to develop during the course of this presentation. Indiana has taken advantage of a low technology and high importation approach to energy historically, and therefore has the possibility of skipping many intermediate, complex high technology systems and going directly to relatively simple high efficiency systems for marginal energy developments. We have an interesting opportunity in Indiana that is not available to some other states that have gone into greater development of expensive synfuel, coal gasification, and nuclear systems.

The fourth hypothesis behind these forecasts is that Indiana will regain control of its own economy and once again experience a growth pattern in real terms after inflation.

Brief History of Energy in Indiana

Before embarking on energy futures, it is necessary to establish a base. Indiana has seen waves of energy production in coal, oil, and gas in various periods. Oil production had a major peak at the turn of the century and again in the 1950s and 60s. Natural gas production was heavy from 1890 through 1910. Coal production has been variable and long lasting and now shows signs of considerable expansion. The history of this production is sketched in Figures 1, 2, and 3.

Consumption patterns, on the other hand, have shown steady growth. Thus, Indiana went from a position of energy independence as a state at the turn of the century to a position of considerable dependence on external resources in 1960. Since that time, production has been growing at the same rate as consumption, with production amounting to roughly 25.0% of consumption. This enduring dependency on external sources is a contributor to the gradual relative decline in economic activity in Indiana. Energy consumption patterns in Indiana from 1960 to 1978 are described in Figure 4.

In terms of energy reserves, Indiana has a major resource in solar energy (which has been utilized in its agricultural industry), coal, oil shale, shale bearing uranium, and relatively minor natural gas and oil reserves. The oil shale conversion is just now entering early experimental stages, while uranium bearing shale is still

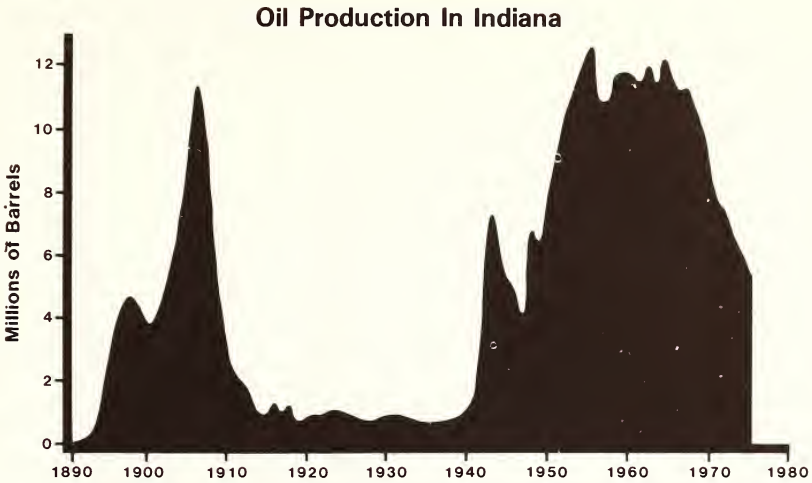

FIGURE 1. *History of Oil Production in Indiana* (SOURCE: Geological Survey, Department of Natural Resources, State of Indiana, Oil Development and Production in Indiana, Mineral Series No. 22.)

a research novelty. Solar applications, although growing, are limited by seasonal variations. Utilization of Indiana's energy resources shows promise of considerable growth in the coming decades.

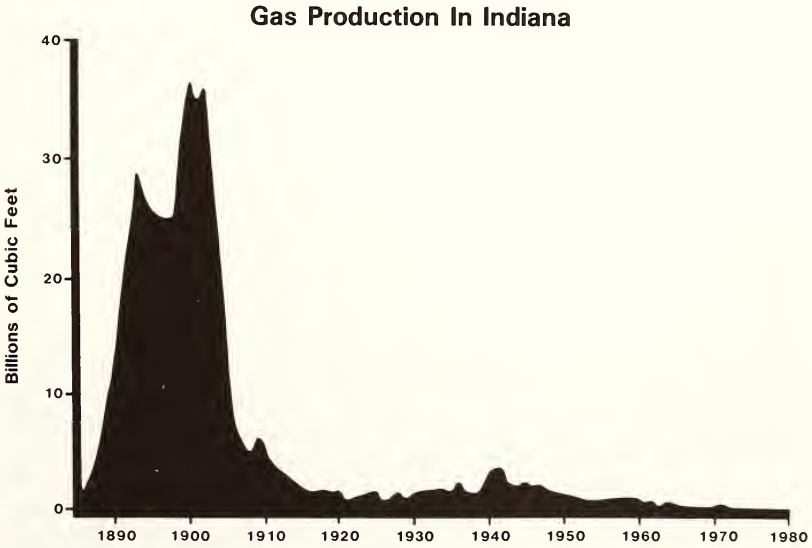

FIGURE 2. *History of Gas Production in Indiana* (SOURCE, Geological Survey, Department of Natural Resources, State of Indiana, Petroleum Industry in Indiana, Bulletin 42-N.)

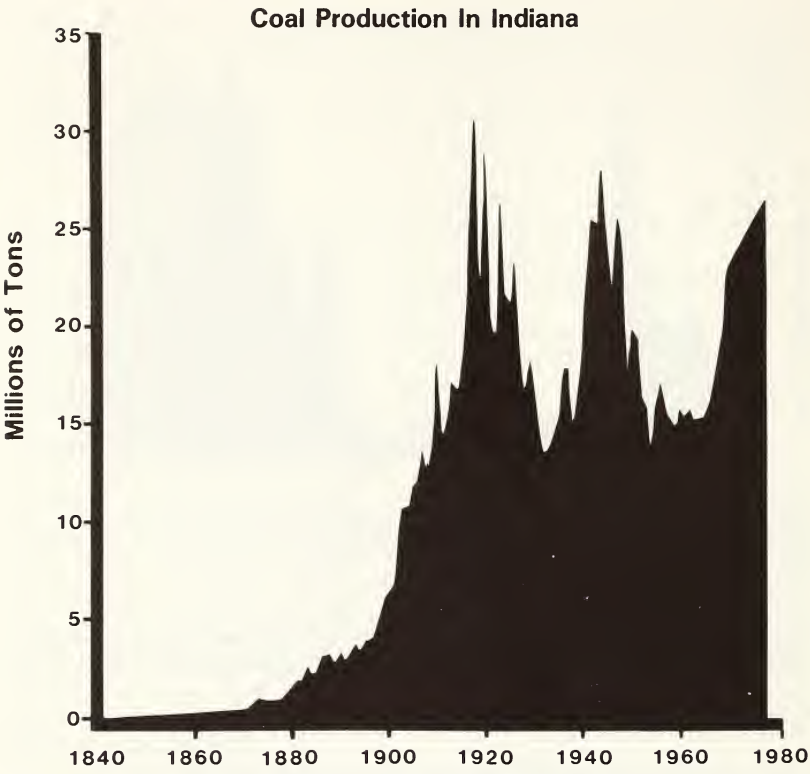

FIGURE 3. *History of Coal Production in Indiana* (SOURCE: Geological Survey, Department of Natural Resources, State of Indiana, Coal Resources in Indiana, Bulletin 42-I.)

Future Energy Patterns in Indiana

In order to maintain a robust economy in Indiana, a 3.0% annual growth in end use or work output from energy sources is required. For purposes of analysis, this growth can be split into three separate parts: (1) conventional fossil fuel consumption, (2) alternative fuels such as solar and nuclear, and (3) increased efficiency in obtaining end use work from conventional and alternative energy sources. Taking 1978 as a base for which firm numbers are available, Indiana's consumption of 2.66 exajoules will grow to an equivalent end use work output (if conversion efficiency remained constant) of 4.80 exajoules in the year 2000. Of this effective increase of 2.14 exajoules, only one sixth, or 0.37 exajoules will appear in standard energy consumption terminology. The rest will be a result of increased utilization efficiency. This change is outlined in Figure 5. The increase in fossil fuel consumption will be 0.22 exajoules to a level of 2.88 exajoules. At the same time, coal will partially replace oil in the fossil fuel category due to pricing pressures on oil. Alternate fuels, principally nuclear and hydro, will show rapid growth to a level of 0.14 exajoules or nearly 5.0% of total consumption. Before breaking these numbers out further, it is worthwhile here to discuss these three segments of the incremental effective energy growth.

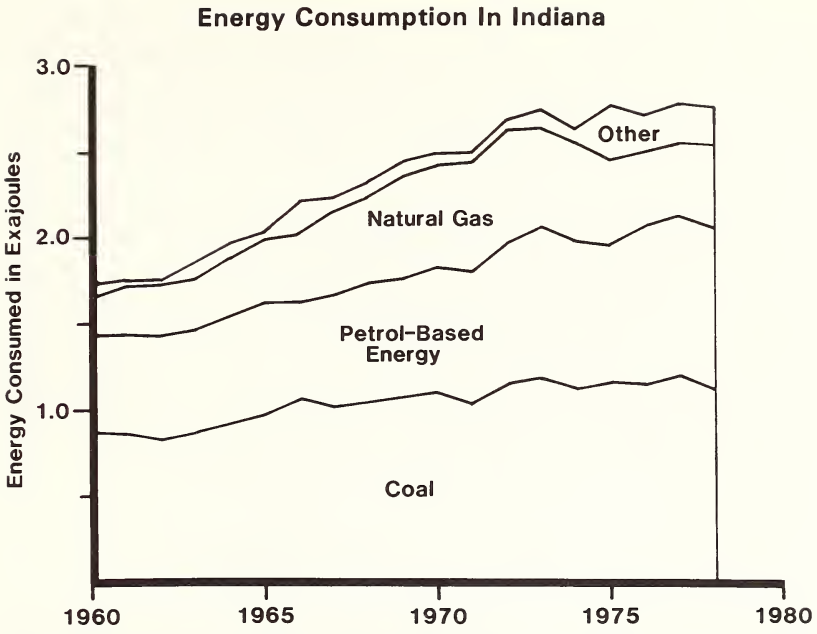

FIGURE 4. *History of Energy Consumption in Indiana* (SOURCE: Indiana Energy Consumption Data Base, SEDS.)

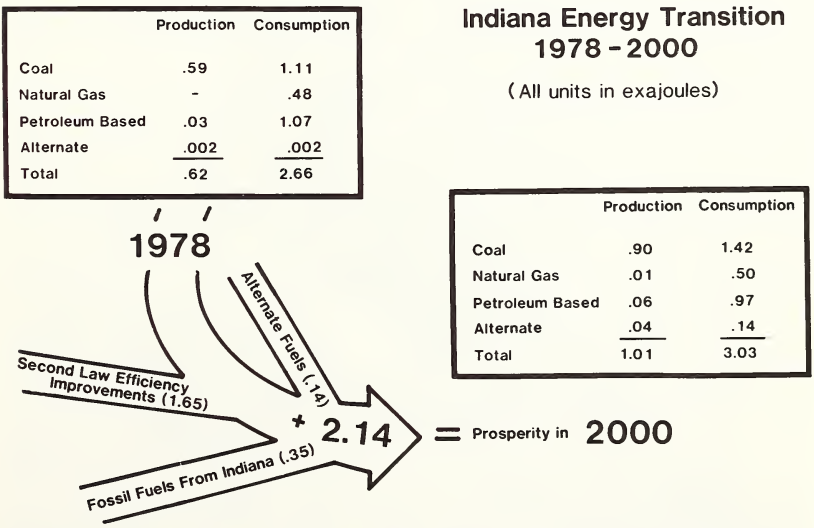

FIGURE 5. *Indiana Energy Production and Consumption—Prediction for the Year 2000.*

1. *Increased energy utilization efficiency.* By far, the most important aspect of this improved efficiency will be in the individual automobile fuel economy. Despite increases in the number of cars in operation, this segment will consume 10% less fuel by the year 2000. Another important activity will be the continued application of microprocessor technology to energy control. These applications will be on a wide range of devices and systems including heating, ventilating, and air conditioning equipment, industrial machinery, and boilers, and other energy conversion systems. An interesting example of this type of system is the residential environmental control by which portions of the home can be heated or cooled according to a programmed input from the homeowner.

Heat recovery systems represent another approach to enhanced energy efficiency. Heat exchangers are more expensive than microprocessors, but will grow particularly in industrial applications as the price of fuel increases. Heat pump applications represent another broad area of improvement in end use energy efficiency. Water sided pumps, in particular, will see growth both in new residential applications and in retrofit situations. A good example of this type of technology is the annual cycle energy system shown in Figure 6. This system provides heat by

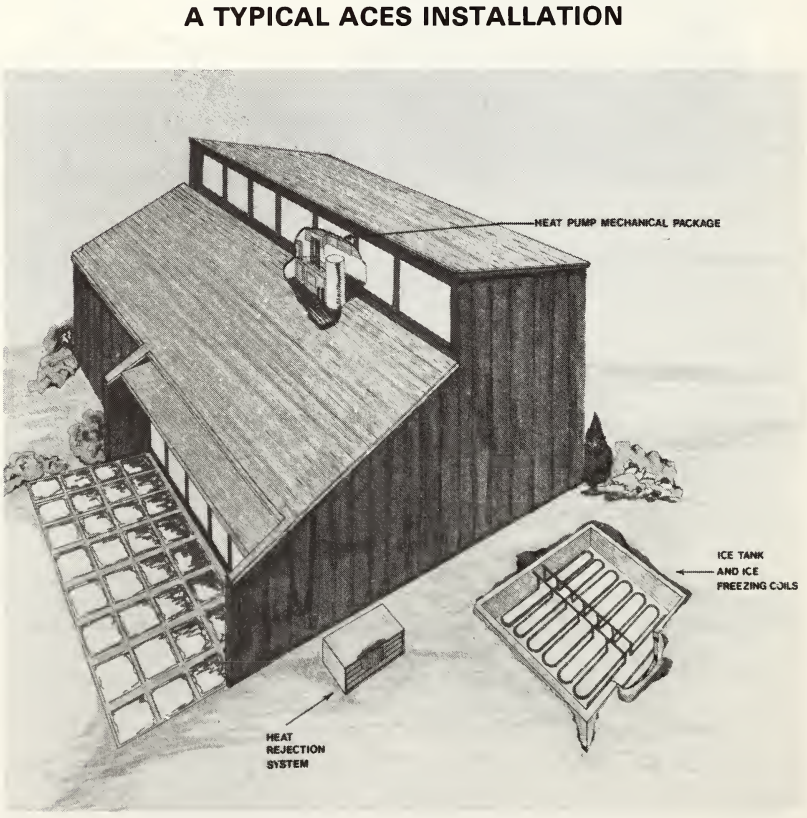

FIGURE 6. *Sketch of an Annual Cycle Energy System*

way of a heat pump in the winter through freezing stored water. The resulting ice is employed to provide cooling in the summer.

Another important set of systems for energy efficiency improvement is that of water heating. Pulse jet gas water heating and solar assisted water heaters are two important examples of these systems. A typical solar system is illustrated in Figure 7.

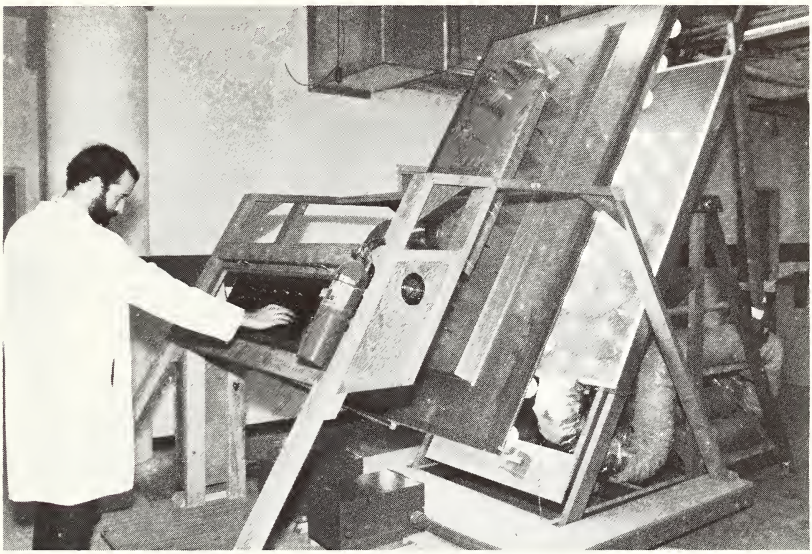

FIGURE 7. *Solar Hot Water Collector under Test at the Indianapolis Center for Advanced Research*

2. *Alternative energy supply.* Solar energy through hydro power presently supplies approximately 0.2% of the energy produced in the state. This amount will rise to 0.01 exajoules due to low head hydro applications by the year 2000. No nuclear electric power is generated in the state at present, but a very small amount is imported from Michigan. Through the addition of one gigawatt-year of nuclear electric power generated in the state, imported uranium will supply 0.10 exajoules or 3.0% of energy consumed in 2000. Alcohol fuels, steam from urban waste, wood combustion, and small amounts of wind and photovoltaic electricity will make up the remaining 0.03 exajoules of nonfossil fuel sources.

3.*Conventional Sources.* Through the growth in use of heat pumps, electric transport and microprocessor controls, coal consumption will grow significantly in the next two decades to about 1.4 exajoules from a present value of about 1.1. Since nuclear will add 0.10 exajoules and efficiency increases in production of electricity will add another 1.0%, the growth in electricity consumption will be 1.7% per year during the next two decades.

On the production side, Indiana will strive to gain back its balance of energy with other states. This will result in holding imports to their present level of a little over 2.0 exajoules. Through large increases in coal production, small hydro increases, and doubling of gas and oil production due to greatly increased exploration

in reaction to higher prices, production will increase to 1.01 exajoules. Thus, coal production will grow by 2.1% per year over the next 20 years to a level of 0.90 exajoules per year or 42 million tons per year. This will result in total production of 1.01 exajoules or roughly one third of consumption.

Environmental and Economic Consequences

Other important aspects of these conclusions fall into the categories of environmental and economic concerns. The first major analysis from the environmental standpoint is the measurement of heat throughput. Based on this study, that throughput will increase by approximately 16% to a level of 3 exajoules in 2000. Assuming a 10% utilization efficiency in 1980, this means a growth of 0.22 exajoules to a level of 0.48 exajoules end work output in 2000. This will be achieved by an increase in energy utilization efficiency to a value close to 16.0% in 2000. Thus, there will be no major environmental effects due to thermal throughput.

The second major environmental analysis must be to review the increased energy production. This will be primarily coal. Much of this coal will be strip mined. Since adequate environmental regulations concerning strip mining now exist, the cost of Indiana coal will remain high and thus, moderate expansion of the levels predicted in this paper of 2.0% per year.

Another result will be a vigorous "mining" of old abandoned coal. These fields which hold massive reserves of coal on the surface in Indiana where entire coal mines once existed will be mined extensively because of cost advantages derived from environmental laws. By the year 2000, this effort will probably yield production levels of 2 million tons per year. Thus, in all likelihood, the net effect of increased coal production will be an actual increase in available land.

The third environmental factor to consider is the shift in consumption from oil to coal. This increase in coal consumption will take place for the most part in electric generation. Present air quality regulations are set to meet external environmental questions such as "acid rain" in the Eastern United States or Canada, or microparticulate problems immediately to the East. Thus, no changes in air quality will be felt in Indiana. Costs of Indiana electricity will be affected by these regulations. These higher costs will also moderate growth.

Other environmental questions related to increases in oil production and alternate fuels are minor. In summary, the result of this change to higher utilization efficiency will bring about minor net improvements in the overall environmental quality of the state.

The economic effect of these moves toward greater utilization efficiency and energy independence will be to provide a basis for growth. Indiana's economy will grow gradually in the 80s and more rapidly in the 90s. The major items produced to accomplish these energy results will be in electronics, computers, and related transducers. A second set of products to be produced will be heat transfer equipment; including regenerators, combustion nozzlers, compressors, storage vessels, and solar collectors.

Conclusions

Thus, this set of predictions closes on itself. Indiana will grow in its production of these items while holding its own in heavy industrial units now produced. The growth industries for Indiana will be electronics, coal, gas, and oil exploration and modular heat transfer equipment.

In conclusion, a few words should be said about "beyond 2000." The set of activities unleased by this energy future will still be building at that time. Transport, agricultural, heating, and ventilating, and industrial energy schemes with energy utilization effectiveness of 25.0% to 50.0% are achievable. Further, a small, but growing alternate energy business will be in place ready to grow. Economic growth will continue with alternate fuels gradually replacing energy utilization efficiency improvements as the driving force in the economy in the mid 21st century.

A set of assumptions, an assessment of the status of energy in Indiana and a subjective regressive study has resulted in a set of predictions showing an attractive future for Indiana.

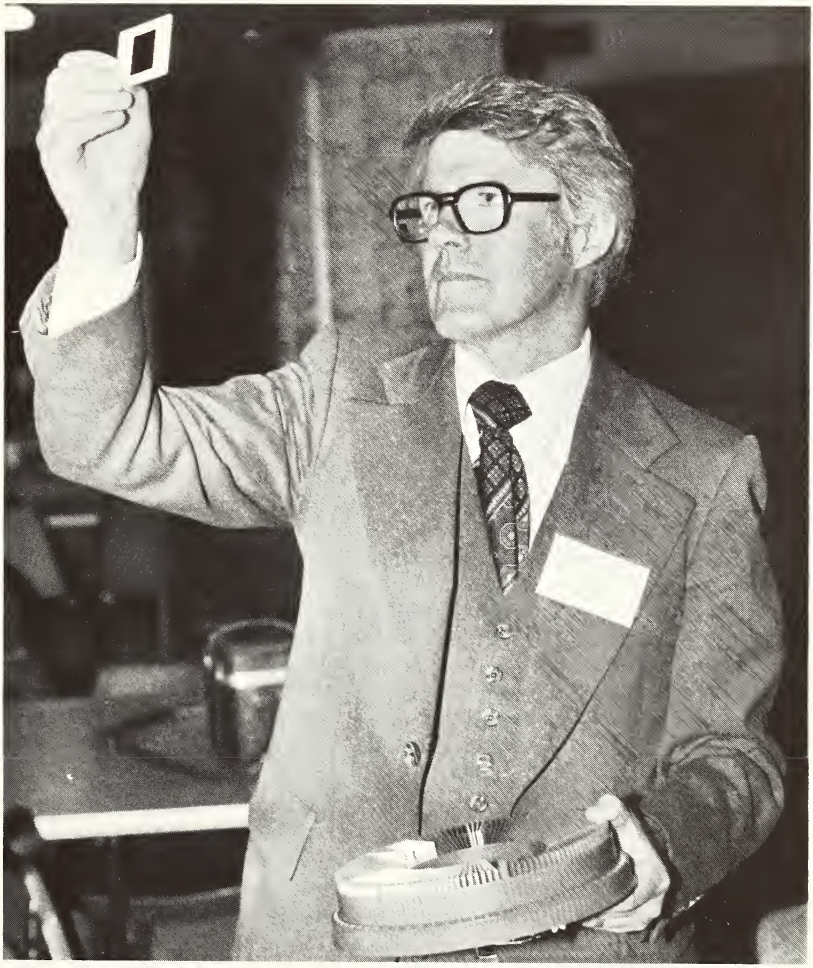

Photo by Lloyd Anderson, IAS

ROBERT E. HENDERSON

Robert E. Henderson checks the transparencies prepared for use with his Presidential Address, "The Energy Future for Indiana."

SIMULATION LANGUAGES' VIEW OF THE WORLD

A. Alan B. Pritsker*, President, Pritsker & Associates, Inc.

Introduction

One of the most important problems facing the United States in the decade of the 80s is to develop methods for increasing productivity. Faced with a scarce money supply, it will be necessary to adapt current production plants to meet new demands or to build new facilities with limited expenditures. Thus, we must make wise decisions to obtain an effective use of both our capital and our technical resources in providing goods and services.

A method for helping decision-makers to make wise choices is modeling and simulation. The foundation of this approach involves obtaining an understanding of the problems and concerns related to the decision to be made. This includes a definition of the factors that affect the decision, a listing of the measures by which a good decision will be judged, and the building of a model that forecasts the measures of performance for each decision alternative. Thus, modeling involves a systems approach to problem resolution and consists of four steps. First, a system is decomposed into its significant elements. Second, the elements are analyzed and described. Third, the elements are integrated in a model of the system. Fourth, performance is obtained through the analysis or simulation of the model.

In this paper, information is provided on modeling for decision-making, simulation modeling perspectives, SLAM, dynamic behavior of manufacturing systems, and simulation modeling application areas.

Modeling for Decision-Making

Models are descriptions of systems. In the physical sciences, models are usually developed based on theoretical laws and principles. The models may be scaled physical objects (iconic models), mathematical equations and relations (abstract models) or graphical representations (visual models). The usefulness of models has been demonstrated in describing, designing and analyzing systems. Many students are educated in their discipline by learning how to build and use models, for example, electrical networks and free body diagrams. Model building is a complex process and in most fields, is an art. The modeling of a system is made easier if 1) physical laws are available that pertain to the system; 2) a pictorial or graphical representation can be made of the system; and 3) the variability of system inputs, elements and outputs is manageable.

Industrial engineers, managers and administrators, management scientists and operations researchers deal mainly with the procedural aspects of manufacturing systems. These individuals and their respective fields are attempting to bring order out of chaos with respect to the understanding of the operation of such procedural systems. For our purposes, procedural systems can be thought of in terms of information flow and decision-making with respect to the implementation of stated or implied policy. Emphasis is placed on improving performance through procedural changes or through new designs regarding scheduling, sequencing, distribution, allocation, layout and similar functions (see Figure 1). The modeling of

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*Indiana Academy of Science 1981-82 "Speaker of the Year"

Strategic Planning

1. Design of new processes
2. Design of new policies
3. Determination of effect of different priorities
4. Design of new systems
5. Forecast of production levels
6. Determination of required resources
7. Estimation of cost of alternatives

Management Control

8. Determination of how to improve throughput
9. Determination of effect of changes in resource capacities
10. Determination of effect of delays in raw materials
11. Determination of how to relieve bottlenecks
12. Determination of effect of change in demand
13. Determination of effect of equipment failures
14. Determination of system efficiency

Operational Control

15. Determination of capacity
16. Determination of bottlenecks
17. Determination of operational requirements
18. Assessment of in-process inventories
19. Determination of utilizations
20. Determination of critical operational rates
21. Determine best manning configurations

FIGURE 1. *Areas of decision-making for procedural systems.*

procedural systems is often more difficult than the modeling of physical systems for the following reasons: 1) few fundamental laws are available; 2) procedural elements are difficult to describe and represent; 3) policy statements are hard to quantify; 4) random components are significant elements; and 5) human decision-making is an integral part of such systems. In the next section the simulation modeling perspectives that aid in the building of models will be described.

Simulation Modeling Perspectives

In developing a simulation model, it is helpful to select a conceptual framework for describing the system to be modeled. The framework or perspective contains a "world view" within which the system functional relationships are perceived and described. The world view provides a conceptual mechanism for articulating a description of the system.

A system is a collection of items from a circumscribed sector of reality that is the object of study or interest. The scope of every defined system and of every model of that system is determined by its reason for being identified and isolated. The scope of every model is determined by the particular problems the model is designed to solve.

Models of systems can be classified as either discrete change or continuous change. These terms describe the model and not the real system. In most simulation models, time is the major independent variable. Other variables included in the model are functions of time and are dependent variables. The adjectives discrete and continuous when modifying simulation refer to the behavior of the dependent variables. Discrete simulation occurs when the dependent variables change discretely at specified points in simulated time referred to as event times. The number of jobs waiting to be processed is an example of a variable that

changes by a discrete amount. In continuous simulation the dependent variables may change continuously over time. The modeling of the concentration of a reactant in a chemical process or the position and velocity of a spacecraft are illustrations of situations where a continuous representation is appropriate. In combined simulation the dependent variables of a model may change discretely, continuously, or continuously with discrete jumps superimposed. For example, when the concentration level of a reactant in a chemical process reaches a prescribed level, the process may be shut down. In the next section, a description of SLAM, Simulation Language for Alternative Modeling, is presented including the mechanisms for building models for discrete, continuous and combined simulations.

Simulation Language for Alternative Modeling, SLAM

SLAM is a simulation language that allows for alternative modeling approaches. It allows systems to be viewed from a process, event, or state variable perspective. These alternate modeling world views are combined in SLAM to provide a unified systems modeling framework. (25)

In SLAM, a discrete change system can be modeled within an event orientation, process orientation, or both. Continuous change systems can be modeled using either differential or difference equations. Combined discrete-continuous change systems can be modeled by combining the event and/or process orientation with the continuous orientation.

The process orientation of SLAM employs a network structure comprised of specialized symbols called nodes and branches. These symbols model elements in a process such as queues, servers, and decision points. The modeling task consists of combining these symbols into a network model which pictorially represents the system of interest. In short, a network is a pictorial representation of a process. The entities in the system (such as people and items) flow through the network model.

In the event orientation of SLAM, the modeler defines the events and the potential changes to the system when an event occurs. The mathematical-logical relationships prescribing the changes associated with each event type are coded by the modeler as FORTRAN subroutines. A set of standard subprograms is provided by SLAM for use by the modeler to perform common discrete event functions such as event scheduling, file manipulations, statistics collection, and random sample generation. The executive control program of SLAM controls the simulation by advancing time and initiating calls to the appropriate event subroutines at the proper points in simulated time. A continuous model is coded in SLAM by specifying the differential or difference equations which describe the dynamic behavior of the state variables. These equations are coded by the modeler in FORTRAN by employing a set of special SLAM defined storage arrays. When differential equations are included in the continuous model, they are automatically integrated by SLAM to calculate the values of the state variables within an accuracy prescribed by the modeler.

An important aspect of SLAM is that alternate world views can be combined within the same simulation model. There are six specific interactions which can take place between the network, discrete event, and continuous world views of SLAM:

1. Entities in the network model can initiate the occurrence of discrete events.
2. Events can alter the flow of entities in the network model.

3. Entities in the network model can cause instantaneous changes to values of the state variables.
4. State variables reaching prescribed threshold values can initiate entities in the network model.
5. Events can cause instantaneous changes to the values of state variables.
6. State variables reaching prescribed threshold values can initiate events.

The ability to construct combined network-event-continuous models with interactions between each orientation greatly enhances the ability to model complex systems.

Modeling Manufacturing Systems (20)

A manufacturing system is a collection of men and machines which operate within an organizational structure to produce a set of products. Production processes are used with the manufacturing system and are affected by financial factors, raw material supplies, union rules, and sales. Surrounding the manufacturing system is an environment that is created by political, social and economic conditions. A need exists for understanding the dynamic behavior of manufacturing systems. This dynamic behavior can be thought of as a plot of system-related variables over a time horizon. For example, plots or tables of interest would be for:

- Profits
- Sales
- Production
- Inventory
- Resource Utilization
- In-Process Inventory
- Equipment and Computer Processing Rates
- Fraction of Jobs Completed On Time
- Scrap Output
- Pollution Emissions

Clearly the list could go on for several pages. The potential variables of interest could reflect the entire business operation associated with the manufacturing system.

In a manufacturing system, there are objects and procedures. The objects are classified as resources or entities where resources represent the elements of the system that are used to produce or affect the entities that are flowing through the system. Both the entities and resources are described by attributes to which values can be given. It is the values of the attributes of resources and entities that constitute the time-varying behavior of the system.

The procedures of system operation cause the attribute values to be changed. Internal to these procedures are decisions that are available to management that can affect system performance.

The objective of a simulation model is to provide a means for describing manufacturing systems and the rules which produce their dynamic behavior. In this way, a method for transforming decisions and procedures into detailed performance measures is made available.

Uses of Simulation Models

Models which portray the time-varying behavior of systems have typically

been used in one or more of four modes as: explanatory devices, analysis vehicles, design assessors, or performance predictors. Simulation models are used as explanatory devices to describe in a logical manner the operation of systems. Describing the details of a system's composition and operation is frequently an enlightening experience, even for those familiar with the system.

When a simulation model is used as an analysis vehicle, the effect of a change in system operation is typically being explored. Common questions posed of such models are: What is the bottleneck area? What increase in throughput results from adding new men or equipment? What is the effect of using expeditors, a new dispatching rule, or a new process plan? How will a ten percent increase in orders affect inprocess inventories, resource utilization, and productivity? Analysis with simulation models may be done without making any changes to the real system, often resulting in significant cost savings.

The design of a new system is always an uncertain and risky undertaking because the potential performance of the system is often unknown. Designers aren't certain that the system will function as designed, especially for large systems. However, a simulation model of a new system design allows one to analyze the system to determine to what degree the system will perform as desired. If the design does not perfrom as desired, it can be modified and reevaluated until it meets specified performance criteria. The ability to experiment with a simulation model of a design is similar to having a prototype system or pilot plant.

Simulation models are also used to forecast the future performance of systems as they change and as their environment changes. Such an application can be done on-line or off-line and is a powerful way of controlling the operation of a system.

There are many types of systems which combine to form a complete manufacturing system. Among these are production systems, computer hardware systems, computer software systems, communications systems and procedural systems. A flexible simulation language like SLAM is able to represent each of these types of systems as well as combinations of them. Production systems include the shop floor hardware used to produce the manufacturing products, such as machines and material handling equipment, as well as the personnel required to support the shop floor hardware, such as operators, foremen and expeditors. Computer hardware systems contain such components as storage devices, processing hardware, and data communications equipment. Computer software systems may consist of any type of computer software used in a manufacturing environment including financial and inventory software support programs. Communications systems are any systems which involve the transfer of information between points in the manufacturing environment, while procedural systems are sets of rules and algorithms for accomplishing manufacturing functions. Systems of these types combine to make up entire manufacturing systems. Thus, it is important to be able to represent them individually and in combination.

Simulation Modeling Application Areas

To illustrate the diversity of problem areas in which SLAM and its antecedents GASP IV and Q-GERT have been used, the following list with references is provided:

1. Computer Systems (1, 16, 17, 37)
2. Communications Systems (13, 14)
3. Environmental and Energy Flows (12, 19, 29, 32, 33)
4. Crop Management and Ecological Studies (11, 20, 24, 38)

5. Transportation Systems (2, 8, 23, 39)
6. Policy Analysis (7, 30, 34)
7. Project Planning and Control (3, 4, 5, 10, 22)
8. Materials Handling and Manufacturing (6, 9, 15, 18, 26, 31, 35, 36)
9. Process Design (21, 27, 28)

Concluding Remarks

Management is looking increasingly to scientists and engineers to perform the complex analyses required to improve productivity within existing energy and environmental constraints. Quantitative analysis within the industrial environment is mandatory if we are to obtain the productivity improvements necessary to maintain the United States' world leading productivity levels. The use of computers as the foundation for modeling, analysis, design and planning is a must for the modern scientist and engineer. The opportunities exist and it is up to us to meet our expectations. Models, simulation, and computers will go hand-in-hand in improving the productive capacity of our industrial complex and the quality of life of our citizens.

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ANTHROPOLOGY

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ABSTRACTS

The Packwood Site: A Plow Disturbed Historic Structure. Gary D. Ellis, Indiana Divison of Historic Preservation and Archaeology, Indianapolis, Indiana 46204.——Controlled archaeological excavation of an apparent plow disturbed early 19th century structure in Bartholomew County has produced evidence for substantial interpretable sub-plow architectural and archaeological features. The physical integrity of sub-plow deposits include the remains of refuse pits and a limestone foundation, internally dressed and extending 3-3.5 ft below plow disturbance. The 10 x 12 ft structure was built during the early 19th century into a sandy terrace overlooking the White River one mile north of Azalia, Indiana. Material culture ranges from ceramics, bottle glass, nails, and clothing hardware (buckles, buttons, suspender clasps) to coins and percussion rifle parts, all characteristic of a mid-19th century residence. Faunal remains recovered from associated contexts include abundant pig, deer, wild turkey, chicken, sheep, fish, aquatic birds, groundhog, and the muskrat and suggests an active use of local wildlife and domesticates as food resources.

Archaeological Investigations at Mounds State Park, 1979-1981. Ronald Hicks, Ball State University, Muncie, Indiana 47306.——Each summer since 1979 the Archaeological Resources Management Service at Ball State University has been involved in archaeological investigations at Mounds State Park, along the White River just east of Anderson. These investigations have included not only excavation but also survey aimed at locating destroyed and previously unknown sites. Survey techniques have included shovel probing, infrared aerial photography, magnetometry, resistivity survey, and simple pedestrian reconnaissance. During the 1979 season testing was carried out in the area of the historic Bronnenberg farm and on the sites of two plowed-out earthworks on the edge of the modern campground; in both areas substantial archaeological remains were found to exist. In 1980 the site of a plowed-out mond adjacent to a surviving earthen enclosure was excavated, revealing that the mound had been an embellishment on the enclosure entrance rather than an independent structure and yielding radiocarbon dates in the first century A.D. The 1981 field season was devoted solely to reconnaissance and survey work, producing information on the location of several small prehistoric sites as well as structures associated with the early twentieth-century Union Traction Company amusement park, a vacation retreat in the northern end of the park from the same period, and the Depression-era Civilian Conservation Corps camp.

Philippine Linguistics: The Concept of Subject and Topic in Tagalog. Helen R. Lim, Department of Linguistics, University of Illinois at Urbana-Champaign, Champaign, Illinois.—— Subject and Topic in Tagalog is a controversial study,

thus linguists have proposed various solutions to the problem. Based on these theoretical explanations, this paper is an attempt to further examine the concept.

Development of a Dendrochonology Series for Central Indiana. ROBERT A. MC DANIEL, Department of History, Purdue University, West Lafayette, Indiana 47907.——Collection of materials for a tree-ring series for central Indiana was begun in 1980. The preparation of the series has two goals: first, the dating of buildings and other wooden materials from the region and, second, dendroclimatological investigations using Purdue meteorlogical data. Materials collected from two sites have so far allowed the preparation of an index extending to 1689. Approximate construction dates of several local buildings have already been established or confirmed by standard cross-dating techniques using the index. Materials are being sought to extend the chronology further into the 17th century. In addition, collection of materials for the climatological investigation continues.

Paleo-Indian Occupation of the Upper Wabash Valley. BRENDA PEASE, Indiana University-Purdue University at Fort Wayne, Indiana 46805 and DONALD R. COCHRAN, Ball State University, Muncie, Indiana 47306.——A survey of Paleo-Indian artifacts from six counties in the Upper Wabash Valley of Northeastern Indiana has shown that the area was inhabited by both early and late Paleo-Indian peoples. A study of the artifacts, raw material sources and site locations has revealed evidence for population movements and data for settlement analysis.

The American Military Conflict in South Vietnam and Its Effect on Negrito Populations of Western Luzon, Philippines. JAMES M. PETERSON, Illinois State Museum, Springfield, Illinois.——The American military involvement in South Vietnam has had a variety of profound cultural and ecological effects on that country and other regions of mainland Southeast Asia. In addition, in such countries as the Republic of the Philippines, American military support activities, the result of political conflict in South Vietnam, also have had a dramatic effect on indigenous Philippine populations. This paper attempts to examine some of these effects as they relate to the Negrito populations of western Luzon, the Republic of the Philippines.

Prehistory, Politics and Contemporary Culture Change. PAUL JEAN PROVOST, Department of Sociology and Anthropology, Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805.——This report will use an archaeological perspective to develop a model for interpreting contemporary social and political changes occurring in the United States of America today. Extensive use will be made of data from Mesoamerican prehistory to show a long term pattern of cyclical culture change. The paper concludes that the social and political events of recent years can best be interpreted as signs that the United States of America is entering a post classic period.

Ball State University Archaeological Field School Excavations for the 1981 Season at the Bertsch Site, Wayne County, Indiana. WILLIAM RESEIGH and B. K. SCHWARTZ, JR., Ball State University, Muncie, Indiana 47306.——The article being submitted is a simple site report for a feature of the Bertsch Site (12 WY 45), a group of circular earthworks in Wayne County, Indiana near Cambridge City. The paper locates the site in its geographic and geophysical setting, reviews previously published material on the site, describes the 1981 Ball State University field school's excavation of a 100 foot, circular vegetal feature thought to be the remains of an earthwork, and describes the findings of the excavation.

The Late Archaic Period at the Blue Grass Site: French Lick Phase in Warrick County, Indiana. WILLIAM R. RHEINHARDT and ROBERT E. PACE, Indiana State University, Terre Haute, Indiana 47809——Previous survey located a one acre area of concentrated midden on a rise that overlooks Blue Grass Creek in northwest Warrick County. Test excavations in the midden followed a controlled surface study. A sample of 14 units found an average of 5 inches of undisturbed midden under a plowzone, 9 shallow pits, and a dog burial. Initial analysis of kitchen midden indicates warm season habitation with subsistence derived mainly from aquatic and floodplain sources. A relatively large number of cutting, scraping and perforating tools suggests fabrication of animal hides and vegetable fibers. Diagnostic artifacts conform to those recently defined as part of the French Lick Phase, with an estimated age of 3,000 to 1,500 B.C.

Geophysical Studies at the Entrance to the "Circle Mound" Earthwork, Mounds State Park, Indiana. ALAN C. SAMUELSON, Department of Geology and RONALD HICKS, Department of Anthropology, Ball State University, Muncie, Indiana 47306. ——The Ball State University Applied Science in Archeology Research Group utilized magnetometer and electrical resistivity surveys in study of earthworks associated with the Woodland Indian cultures. The archeological study concentrated on the entrance area to the "Circle Mound" in Mounds State Park near Anderson, Indiana. The site consists of a rather large east-west oriented central area surrounded by a trench and rim. Of principal interest at this time was the survey of mounds located on either side of the entrance to the large enclosure. These two mounds were reported in early publications but they were plowed over with cultivation of the area east of the enclosure. Similar distinctive patterns of magnetic and resistivity anomalies are centered over the supposed two entrance mounds. Different magnetic and resistivity anomaly combinations are related to the rim, trench, entrance mounds, and plowed ground. Soils and site excavation data are also related to the geophysical data. In addition to supplying useful detail to define this site, geophysical techniques show promise for use at other sites.

Test Evcavations at the Multi-component Clark Site, Southwest Vigo County, Indiana. DANIEL P. THIEL and ROBERT E. PACE, Indiana State University, Terre Haute, Indiana 47809.——The Clark Site is one of a series located on a natural levee along a former course of the Wabash River. Earlier salvage excavation at the nearby Farrand and Wilson sites recorded significant information from Havana, Vincennes and Albee components. A surface reconnaissance of the Clark Site found evidence of an additional Riverton component, along with Havana and Albee. Test excavation has revealed a mixture of cultural debris in a plowzone, and an average of 4 inches of midden below a plowzone. Snyders points and Havana ceramics appear to be related to an adjacent clay-capped mound, similar to one previously examined at the Wilson Site.

The Early Archaic and The Swan's Landing Site. CURTIS H. TOMAK, Indiana Department of Highways, Martinsville, Indiana 46151.——The Swan's Landing Site is located near New Amsterdam, Harrison County, Indiana. The site is exposed in and eroding from alluvial deposits forming the bank of the Ohio River. For a distance of several hundred feet along the river, the bank and the adjacent beach are littered with a large quantity of archaeological material. Hundreds of artifacts including points, bifaces, drills, and end scrapers are known to have been collected from the site, and much chert debris, charcoal, and bone are present. In addition, several areas or strata containing much charcoal, fired earth, chert debris, and arti-

facts exist in the face of the bank buried about three to five feet below ground surface. Some of them appear to be hearths.

The most diagnostic artifacts from the site are the points, and virtually all of them are of one type. They are like Early Archaic Charleston Corner Notched points for which radiocarbon determinations from elsewhere in the Ohio Valley indicate an age of over 9000 years. It is also of considerable significance that, based upon data from other sites, the other kinds of artifacts from Swan's Landing are known to occur in Early Archaic contexts.

In sum, the Swan's Landing Site appears to be a very productive, virtually single component, buried Early Archaic site which possesses features and materials in good archaeological context. The site is significant for a number of reasons, and it has considerable potential for making meaningful contributions to our currently limited knowledge of the Early Archaic in the eastern United States. Data from Swan's Landing can also contribute to research in other disciplines, e.g. paleoenvironmental research and archaeomagnetic studies.

I have been conducting research at the site, and archaeological work needs to be continued there. I hope to undertake archaeological excavations at Swan's Landing in the near future. In this regard, I would like to thank the Indiana Academy of Science for providing me with a generous research grant to fund archaeological work at the Swan's Landing Site.

A Reappraisal of the Batak of Palawan, Philippines, in Light of New Field Data. CHARLES P. WARREN, University of Illinois at Chicago Circle, Chicago, Illinois 60680.——Ethnographic accounts of the Batak of Palawan, Philippines, were collected in 1950-51 and subsequently were reported intermittently in the literature between 1961 and 1977 by Warren. Currently the Batak are being restudied by another enthnographer, James Eder, and his reports provide new data that placed the earlier reports in a different perspective. A point-by-point comparison of the two sets of data provides insights that suggest that the disparities between the sets of data are due to more than the differential training, experience, and field methods of the ethnographers.

Test Excavation Conducted at the Breeden Site 12 Hr 11, in Harrison County, Indiana

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Introduction

The Breeden Site (12 Hr 11) is located in Harrison County, Indiana and extends along the bank of the Ohio River for a distance of 500 feet in the NW 1/4 of Section 35, T4S, R2E, approximately midway between mile 657 and mile 658, some 3500 feet below the mouth of Indian Creek.

The site has been known for many years by collectors in the area, but was first officially reported in July, 1964, by John Dorwin, then a graduate student at Indiana University. Dorwin was at that time conducting an archaeological survey for Indiana University, under contract with the National Park Service in areas of the Ohio River Valley that were to be affected by the construction of a new system of navigation dams. The site is a shell midden, and is located on the right bank of the Ohio River in an area that has been progressively eroded away during periods of high water. The new navigational dam at Cannelton was to raise the pool level at this point some 12 feet, and would likely cause erosion to that place more rapidly than it had before. The site is located farther up the Ohio River than other shell middens which had been investigated at the time of the excavation, the summer of 1966.

This threatened destruction of the site by erosion together with the geographically marginal position it held in the Shell Midden Archaic complex of the Ohio Valley made it desireable that this site be examined by a limited test excavation. A major goal of the excavation was to determine the potential significance of the site. Therefore, assessments of midden depth and the recovery of controlled samples of comparative cultural material were important considerations.

At the location of Site 12 Hr 11, the river flows almost due north. When the greater three or four mile stretch of river centering on this location is taken into account, it is noticed that it is the beginning of a long, gentle left curve in the river course, causing the direction of flow to change gradually to the northwest. It is on such long bends in a river that extensive sand bar development takes place, and in turn, these sand bars provide excellent habitats for freshwater clams. It is presumably because of the presence of these optimal conditions for this form of clam that the prehistoric populations responsible for the midden accumulation chose such sites for long term and/or recurrent habitation in this area.

The site is located in the Crawford Upland physiographic region in its most southeastern corner, closely bordered by the Mitchell Plain on the East. The Crawford Upland, is described as an extensive region of stratified sandstones, shales, and limestones of the Chester Series (Upper Mississippian) which is overlain by the highly resistant sandstones and other rocks of the Mansfield Formation (Lower Pennsylvanian). Topographically the region is marked by an extremely diverse terrain with acute local variation in relief, producing what is probably the most "rugged" and scenic area in Indiana (Schneider 66:47). The site is located in an area where, as one proceeds downriver, the flood plain on the Indiana side of the river changes abruptly to high limestone bluffs overlooking the river, while correspondingly the floodplain on the Kentucky shore expands.

Excavation

An area was selected for excavation which was at the location of the deepest deposit of shell, as judged by the shell level exposed on the eroded bank. A trench was staked paralleling the bank of the river on a north-south axis which was five feet wide, 45 feet long, and marked off in five feet sections. As is indicated in Figure 1, the stakes are numbered south from grid line 100-S, and east from grid

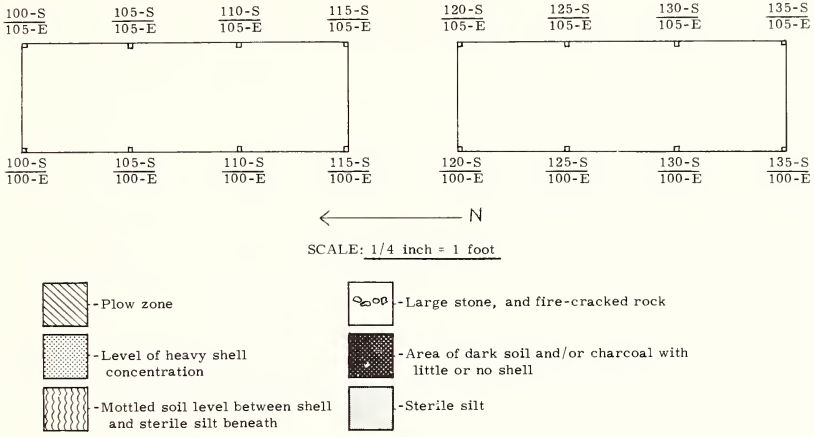

FIGURE 1. (*key to grid system and legend to symbols used in Figure 2.*)

line 100-E. A temporary bench mark was established by driving three 60-penny spikes in the bases of three large elm trees on the bank of the river. Each five feet section is designated herein by the S and E grid values of the stake in its SE corner. By this system, then, the northermost grid section of the excavated trench is designated as 105-S/105-E. Depth was calculated from a datum established at stake 100-S/105-E which was arbitrarily designated as "0" elevation.

The excavation was conducted using 1 foot arbitary levels, except where the conditions required greater controls, at which point the levels removed were reduced to 0.5 foot. Cultural material was recovered above and below the level of heavy shell concentration using ¼ inch mesh hand screens, but the coarseness of the shell-bearing strata, together with the extremely moist conditions at the site, made the use of screens in this level impractical. Instead, midden material was removed with spade and trowel, and was systematically sorted by hand.

Unfortunately, at the time of the excavation, the present writer as principal investigator was unfamiliar with the techniques of water screening and flotation. Both of these techniques could have been rather easily, and most certainly productively used at the site. An effort to return to the Breeden Site in 1973 to re-excavate it with the use of the improved field methods did not materialize because of a failure to obtain permission from the property owner. Therefore, only the larger artifactual and faunal material were recovered.

In all, 7 five feet grid units were excavated. Five were taken down to 6 feet below datum (105-S/105-E, 115-S/105-E, 125-S/105-E, 130-S/105-E, 135-S/105-E), one was taken to 7 feet (110-S/105-E), and one was excavated to 2 feet (145-S/105-E). The trench was removed in two units of 15 feet each, leaving one five feet section stand-

ing unexcavated between the excavated sections. A profile of the stratigraphy of the trench is presented in Figure 2, which accounts for 30 feet of the excavated trench. Seciton 145-S/105-E was only excavated to the 2 feet level due to the limitation of time. Because this depth has barely reached the upper surface of the shell-bearing level, it is excluded from the profile drawing as insignificant in relation to the total depth of the test.

Additionally a five inch soil auger was used to test for possible buried cultural horizons to a depth 3 feet below the 7.0 feet floor of square 110-S/105-E. It was found that the yellow sterile silt extended homogeneously from approximately 5.3 feet to the 10 feet level.

Stratigraphy

In total, five distinct strata were observed throughout the extent of the excavation. The uppermost level was the disturbed plow zone. This zone could be readily distinguished in the trench walls, and averaged seven inches in depth. The second level was a stratum of silt between the top of the shell-bearing level below it and the plow zone above. This deposit produced relatively large amounts of cultural debris in all forms, and it was distinguishable from the other levels in that: 1) there was virtually no fresh-water clam shell present; 2) it was the only level producing ceramic material; 3) it was characterized in the walls of the trench by the presence of extensive amounts of large fire cracked rock. The third level is the shell midden proper, or the stratum which was characterized by an extremely heavy and virtually uninterrupted deposit of the fresh-water clam shells. The soil within this level was very dark brown to black in color, which, along with the visible

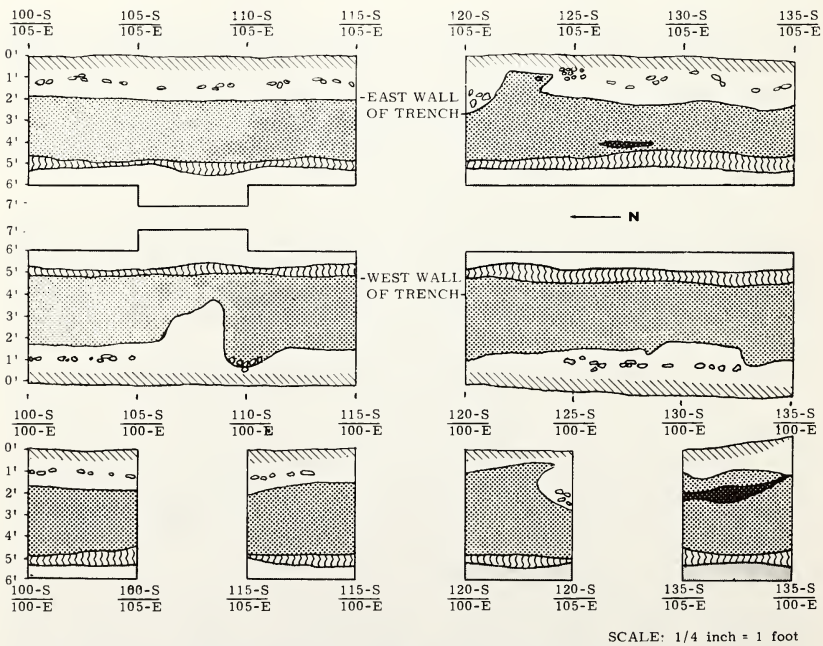

FIGURE 2. *(profile view of test trench walls)*

cultural remains (e.g. lithic debris, bone, etc.), indicated the high organic content of the soil from long and/or repeated occupation of the site. This level ranged from 3.0 feet to 3.5 feet in thickness and changed abruptly to the next lowest level, a stratum of mottled dark and light soils which bore only scant amounts of cultural debris and again virtually none of the clam shell. Immediately below this mottled stratum, a level of yellow-brown sterile silt marked the prehabitation level of the site.

Materials Recovered from and Features Recorded in the Site

Three features were observed and recorded in the excavation.

Feature 1: This feature is a pit which is represented in the profile of the west wall, square 110-S/105-E, in Figure 2. It was obvious that this pit was a late intrusive feature since the fill of the pit was the same soil as that in the pottery-bearing level which overlaid the shell midden. Also, no shell was present in the fill. The feature was only partially excavated because it extended into section 110-S/100-E, an unexcavated unit. The pit appeared to be ovoid in horizontal section, and was bordered on its south side by a mounding of shell and stone which arose above the general upper margin of the shell. This mounded material appeared to be the fill accumulated from the original digging of the pit. The late intrusive nature of the feature is a conclusion based solely on the relationship it had with other strata in the site, and was not confirmed by the presence of late cultural debris in the pit itself; the only debris recovered was undiagnostic lithic debitage.

Feature 2: This feature also was a pit, located in the NE corner of section 125-S/105-E. This pit is given the same interpretation as Feature 1, (i.e., a late intrusive pit). Also like Feature 1, this pit is marked by a mound of back fill material on its southern margin, and its content was almost exclusively fire cracked rock. This feature also was only partially excavated since it extended into unexcavated portions of the site.

Feature 3: This feature was a small (one foot in diameter) area of bured soil with a high concentration of fire cracked rock mixed with clam shell. It was located in almost the exact center of section 130-S/105-E, 3.3 feet below datum. A radiocarbon specimen (C 14 #1) was recovered from this feature, and has been sent for dating.

Burials: No human burials were found in the site, though one isolated human ulna was found in section 125-S/105-E at the 5 feet level without associations or other human remains.

Artifact Inventory: The following is a description of the various artifact types employed in the analysis of the material.

Projectile Points

A wide variety of projectile points were recovered during the excavation. The majority of these points are side-notched varieties common to the later periods of the general Eastern Archaic. Munson and Cook (1980:495) have analyzed the projectile points from the Breeden Site, and have published the following distribution of point types by level (note: Munson and Cook have combined the 6 excavation levels into 3 for purposes of their analysis).

Type	Breeden		
	Lower	Middle	Upper
Matanzas			
Modal	3	7	2
Deep Side Notch	0	2	4
Faint Side Notch	0	1	2
Straight Stem	0	0	2
Flared Stem	0	0	3
Matanzas Other	0	0	2
Sub Total	3	10	15
Godar/Big Sandy II	1	1	1
Brannon Side Notch	2	0	0
Salt River Side Notch	2	1	1
Sub Total	5	2	2
Miscellaneous	2	2	6
Grand Total	10	14	23

A representative sample of these points is illustrated in Plates 1-4.

Drills

Eight drills and drill fragments were found. Three are only point fragments and are virtually useless for identification. Of the five identifiable drills, three distinct types are present.

Type I—Expanded base-three of the drills of this type, frequently called a "T" base drill.

Type II—Expanded base, side notched-like Type I with side notching.

Type III—Globular base—a small drill point (1.0 cm.) extending from a dislike globular base or handle which is roughly 4.5 cm. in diameter. One of this type is present.

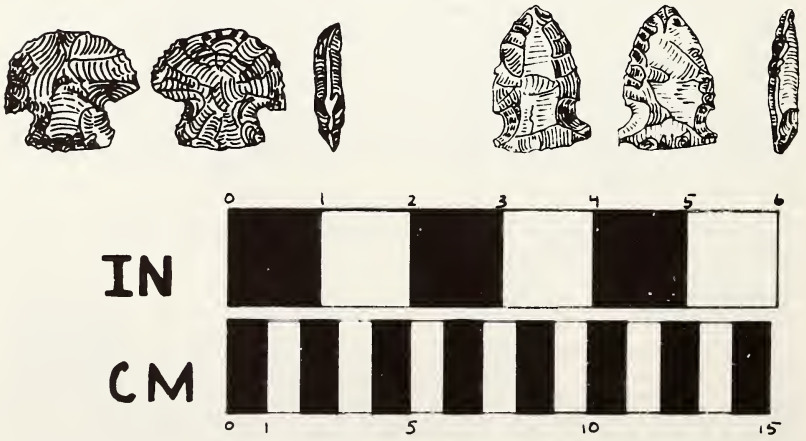

PLATE 1: *Hafted end scraper (Middle Woodland Corner-Notched) and projectile point (Matanzas, Deep Side-Notched) from 0-1' Level (Plow Zone).*

PLATE 2: *Projectile points from 1'-2' level: typological identifications are, left column, from top to bottom, Late Archaic Stemmed, Matanzas-Flared Stem, Matanzas-Faint Side Notched, Matanzas-Cluster, Matanzas-Deep Side Notched, type undetermined; center column, top to bottom, Adena Contracting Stem, Matanzas-Modal, Matanzas-Faint Side Notched, Rehafted blade, Middle Woodland Corner Notched, Matanzas-Straight Stemmed, Matanzas-Flared Stem; right column, top to bottom, Matanzas-Deep Side Notched, Matanzas-Faint Side Notched, Matanzas-Deep Side Notched, type undetermined, corner notched undetermined, Matanzas-Flared Stem, Matanzas Cluster.*

PLATE 3: *Projectible Points: top group from 2'-3' level; the typological identifications are from left to right, Palmer-Corner Notched, Barbed Blade of undetermined type, Godar-Raddatz; bottom group from 3'-4' level, and the typological identifications are upper point, left of center, type undertermined; upper point, right of center is Matanzas-Modal; left column, top to bottom Matanzas-Modal, Matanzas-Modal, Matanzas-Deep Side Notched; center column, top to bottom, Matanzas-Modal, Matanzas-Modal, Matanzas-Modal, Matanzas-Modal; left column, top to bottom, Salt River Side Notched, Matanzas-Faint Side Notched, Matanzas-Modal.*

PLATE 4: *Projectile points from 4'-5' level: the typological identifications are left column from top to bottom, Brannon-Side Notched, Matanzas-Modal; center column from top to bottom Rectangular Lanceolate of undetermined type; Salt River-Side Notched, Matanzas-Modal; right column from top to bottom Matanzas-Modal, Big Sandy II.*

Scrapers

A representative sample of the scrapes is illustrated in Plate 5.

Type I—side-notched end scraper—most easily described as a side notched point with a tip either broken and retouched or originally manufactured to be used as a hafted end scraper. Twelve of this type were recovered.

Type II—End scraper—This is a scraper from, usually rectangular or long ovoid in shape, with a scraping edge usually finished on one or both ends. In 13 of the 18 end scrapers represented, they were made from a long unshaped blades with a retouched scraping end unifacially flaked.

Type III—Side scraper, unifacially worked—This type is represented by a limitless variety of basic flake shapes with one or more edges retouched on one face as a scraping or planing edge.

Type IV—Side scraper, bifacially worked—basically the same as Type III with the addition of bifacial working on the scraping edge. These scrapers often appear to be fragments of large points or pre-form blades, with one or more edges showing the wear and polish of scraping activity.

Type V—Notched scraper—Scraper type commonly referred to in Old World prehistory as a "spoke shave." The scraping edge of this tool has a distinct and well-worn notch in the scraping edge, possibly for use in scraping and polishing a shaft of some sort.

Cores

No basic form or pattern can be discerned among the 12 cores recovered. Any piece of chert or flint from which basic flakes have been intentionally and repeatedly removed has been so designated.

Worked Flint

This category is used as the proverbial "catch all" category into which I have placed all chipped stone artifacts which have unidentifiable shapes.

Utilized Flakes

These are small and highly variable flakes which show evidence of being used as cutting or scraping tools but which show no evidence of having been intentionally shaped or worked for this purpose.

PLATE 5: *Top group, hafted end scrapers, all levels; bottom group, side and end scrapers on flakes, and one "spoke shave" in lower left corner, all levels.*

Ground Stone

Bannerstone—The single bannerstone is a fragmentary find, approximately ¾ missing. It is drilled, made in the pique shape, and is of banded slate.

Nutting Stone—This is a single large piece of sandstone which on one surface exhibits a small depression which appears to have come from a pecking activity.

Worked Antler and Bone

Antler projectile points—Five points, made of antler tines with ground points and hollowed bases, were found.

Utilized, undrilled antler tine—Four tools were found which showed some blunting on the tips from use as a kind of blunt-ended awl or punch. Possibly they were used as flint knapping tools.

Cut and engraved bone—Pieces of bone artifacts exhibiting engraving and/or cutting activity. Six pieces were present.

Bone pins—Long polished pieces of bone with almost parallel sides and gently rounded tips. Eleven fragments are represented.

Bone awls—Pieces of bone, both bird and mammal worked to a sharp point.

Unidentifiable worked bone—Pieces showing shaping or working, but with not enough detail for analysis.

Faunal Remains

Large quantities of bone and shell were recovered from the site, and a preliminary analysis of the bone indicates the following:

". . . There are a total of 1590 items, of these 409 are (tentatively) identifiable deer. Two hundred and forty-eight (248) are from other species with (at this point in the analysis) four species of turtle, 94 items; 14 aves items; 23 drum items, 9 other fish, including a number of cats; also in the assemblage are 2 (or more) racoons, dog-foxes, squirrel, elk and between 8 or 15 deer. . . ." (W. Fred Limp, personal communication)

Ceramic

The ceramic material recovered from the site is represented by a total of 10 pot sherds from the top two feet of the site. Three types have been identified.

Type 1—A course, heavy, grit-tempered ware with the inside surface smudged. The temper appears to consist mostly of large pieces of crushed quartz which are irregular in size. The outer surface is plain, rather open and porous, and light red-brown in color, while the inner surface is burnished and black. The wall of this ware varies in thickness from ½″ to ¾″. Only one sherd of this variety was recovered.

Type 2—A course grit-tempered ware. This ware has thinner walls (¼″) than Type 1 (above) and on one scherd, the outer surface is fingernail impressed. Other than these two characteristics of surface treatment and wall thickness, however, Type 2 is very similar to Type 1. Three sherds of this variety were recovered.

Type 3—A delicate, thin-walled cord-marked ware. This ware is thin-walled (1/8″) and grit tempered. The temper is very fine and the surface of the vessel has a fine "sandy" feel in texture. The color is uniformly

black throughout the sherd wall and the exterior is marked by fine, parallel cord impressions. Six sherds of this variety were recovered.

Radiocarbon Specimens

In all, six specimens were recovered from the 1.5 feet level to the 5.0 feet level. These specimens have been evaluated in the laboratory, and only one is thought to have a sufficient mass to serve for dating purposes. This specimen consists primarily of wood charcoal collected from the dark lens of charcoal approximately 4.5' below 0' in Section 130-S/100-E (see Figure 2). This sample was processed by Dicarb Radioisotope Company and dated by their laboratory with a radiocarbon age of 4210 ± 200 yearsB.P. (DIC-2367) or approximately 2260 B.C.

The following is a listing by quantity and level of the various materials described above.

Artifact Inventory

Artifact	Level Totals					
	0-1′	1-2′	2-3′	3-4′	4-5′	5-6′
Lithic, chipped						
Projectile points	4	21	7	13	8	1
Drills						
Type I	2	1	–	–	–	–
Type II	–	1	–	–	–	–
Type III	–	1	–	–	–	–
Scrapers						
Type I	1	6	–	1	3	1
Type II	–	6	2	8	2	–
Type III	13	16	5	6	5	2
Type IV	1	4	–	1	1	–
Type V	1	–	–	1	3	–
Cores	–	5	1	–	3	2
Hammer Stones	–	4	–	–	1	–
Worked Flint	16	101	35	35	29	7
Utilized Flakes	30	164	46	53	47	–
Lithic, ground						
Bannerstone	–	–	–	1	–	–
Abrading Stone	–	2	–	–	1	–
Nutting Stone	–	1	–	–	–	–
Lithic Debris	658	3181	1131	1619	1651	992
Worked Bone and Antler						
Antler Projectile Points	–	5	–	–	–	–
Antler Flaking Tool	–	1	–	1	2	–
Cut and Engraved Bone	–	2	2	–	3	–
Bone Pins	–	1	3	5	2	–
Bone Awls	–	2	3	4	2	–
Unclassified Worked Bone	–	2	1	1	2	–
Faunal Remains						
(Bone, shell, antler, teeth, turtle shell)	30	586	314	528	489	53
Ceramic						
Type 1	1	–	–	–	–	–
Type 2	–	3	–	–	–	–
Type 3	–	6	–	–	–	–

Conclusions

As was earlier stated, the goal of this excavation was twofold. First, it was the intent of the investigation to recover enough of a sample of the cultural material of the site to be able to make a comparison with that which has been recovered from other shell middens in the Ohio Valley. Though the extent of this excavation was not thorough enough to permit a statistical statement, some brief but useful observations can be made.

The site is clearly a multi-component site with Late Archaic the predominating cultural presence, but with a fair representation of Early Woodland cultural materials (e.g. contracting stem points and heavy grit tempered pottery) and some small presence of Middle Archaic and perhaps Early Archaic. These components were also found to be generally in the proper stratigraphic sequence. The Early Woodland materials were confined to the upper two excavated levels (0'-1' and 1'-2'), and the levels below 2', the shell midden proper, produced exclusively Archaic materials.

Though the lithic debitage has not been systematically analyzed, a rough sorting suggests several interesting patterns. The lithic waste contains a large number of decortication flakes, and primary flakes removed from decorticated cores. At least one blank and several preforms are present, therefore on-site knapping for preform and artifact production was definitely one of the activities undertaken by the inhabitants of the site.

The raw material represented by the debitage is almost exclusively of the classic Harrison County variety, a chert which is of an excellent quality and which is readily available at several sources near the site. However, over half (56%) of the projectible points from the site are of non-Harrison County cherts. This suggests that either the inhabitants and/or the projectile points were relatively mobile within the Ohio Valley and were not confined to the immediate vicinity of the site.

Certain artifact types and features often associated with the shell midden Archaic complex are either poorly represented or absent at this site. Examples of these artifacts would be the bannerstone, atlatl hooks and handles, and other bone tools such as the fish-hook.

Throughout the midden level, large quantities of fire cracked rock were recovered, suggesting that this was more than a temporary camp site for shell fish collecting. The relatively large size of the midden, over 500 feet, when measured along the river bank, also would indicate an extensive occupation at the site. In general, however, none of the features which one would expect to record in a village situation were present, save the two pits, Features 1 and 2. No evidence of either prepared house floors, post molds, or burials were observed in the site, though collectors have reported burials from the area.

The most likely explanation for the absence of evidence for village development is the small size of the excavation. The exposed shell in the bank of the river indicates a NS length of over 500 feet. Though the EW distance is unknown, it is safe to estimate this distance as averaging not less than 20 feet, and quite likely as much as 30 to 40 feet. From this perspective, the 1966 excavation opened an area of 150 square feet in a site of potentially 10,000 to 20,000 square feet, or approximately 1.0%. This limited sample may well explain the absence of some of the more common traits of the shell midden Archaic complex.

In the upper two levels of the Breeden Site there is a small representation of both Middle Woodland corner-notched points and the Early Woodland Adena-like

contracting stem point (See Plates 1 and 2). Also in the upper three levels there are several corner-notched points, two of which appear to be of an Early Archaic type similar to the Palmer or Kirks point (only one is illustrated in Plate 3, top group). However, the projectile points are on the whole dominated quantitatively by a variety of Late Archaic side-notched forms, most notably of the Matanzas group.

In contrast to the Late Archaic Riverton-like cultures of the last two millenia B.C., there are no microtools present on the Breeden Site. This observation plus the dominance of the side-notched points often associated with the Indian Knoll phase in Kentucky suggests that the Breeden Site should date somewhere in the third millenium B. C. Jansen (1971:377) has published three radiocarbon dates from the Old Clarksville Site, a shell midden near the Falls of the Ohio in Clarksville, Indiana. Two of these date are identical, 2510 B.C. ± 180 and the third one in 2230 B.C. ± 180. These three dates from similar sites some 75 miles upriver agree nicely with the date of 2260 B.C. for the Breeden Site. Together, these dates suggest that the Breeden Site was occupied during the second half of the third millenium B.C.

The second, and originally the primary, goal of the excavation was to test the extent of the shell deposit to determine if this site is significant enough in size to merit a more complete salvage effort before it is more extensively damaged by high water. In general, the shell layer itself averaged approximately 3¼ feet in thickness. The configuration of this shell layer suggested that it was a part of a lens-like deposit with its heaviest deposition on the west side of the trench (where it has already eroded away) in that it is consistently thicker on the west side of the trench than it is on the east side. Yet, it is, with present knowledege, impossible to say if the lens development viewed in the test is the major deposit in the site, or even if there is a single major area of deposit. The central ½ of the midden, as surveyed along the bank, seems to be equally heavy in its shell deposit in all places. The tenant farming the adjacent field claimed that some ten years ago shell had been plowed to the surface in areas where stumps had been removed over 200 feet back from the bank. As one walks this field when it is freshly mowed, it is impossible to discern a single rise or mound configuration that would indicate a center or high point for the midden, but gentle undulations in the surface topography of the field do suggest the possibility of several lenses of shell accumulation. At present, it is impossible to judge accurately if this midden is constructed of many small "mounds" or represents one extensive shallow deposit.

A recent (January 1981) visit was made to the Breeden Site to investigate the extent to which erosion has progressed since the excavation in 1966. The results of progressive erosion have been truly disastrous. The bank of the river formerly sloped from the site (40′ above water level) down to the river's edge at a 45° angle. This sloping bank was also formerly covered with trees and thick brush. Now the bank drops precipitously from the edge of the remaining site down to the river's edge. The shore line is now littered with the trunks of huge trees (2′ to 3′ dia.) and cultural debris. It is unfortunate that one must conclude that what now remains of an extremely rich and well preserved multi-component site will be totally destroyed within the next decade.

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Finally, I would like to point out that the total number of projectible points listed in the citation from Munson and Cook differs in total number from the later artifact inventory. The more refined count is that of Munson and Cook and indicates that some of the bifacial material I originally classified as projectile points were not acceptable to their later analysis.

Mandibular Sexing Functions for the Prehistoric Lower Illinois Valley

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Sex determination in archaeological skeletons is necessary to many studies concerned with the reconstruction of prehistoric lifeways, including paleodemography, the analysis of the social dimensions of mortuary practice, and the diagnosis of past health and disease states. Methods for sex assessment of bones range from partly subjective visual observation of gross morphological indicators to more objective statistical analyses of measurements. For examples, see Stewart's (20, 21) and Krogman's (14) reviews of observational methods, Keen (13) for a univariate approach, and Ditch and Rose (4), Garn *et al.* (5, 7, 8, 9), Giles (10), Giles and Elliott (11), Potter (19), and Thieme and Schull (22) for multivariate techniques. The present study employs multivariate discriminant function analysis, a means of statistically maximizing the distance, or differences, between two or more groups, to determine sex on the basis of mandibular measurements.

Birkby (1) and Henke (12) have shown that expressions of sexual dimorphism are population specific. A prehistoric Lower Illinois Valley Indian sample, because of its general homogeneity, is chosen for the present study over a cadaver population. The mandible is selected for analysis because it is a thick and structurally strong bone, known to exhibit sexual dimorphism, and apparently capable of withstanding the vagaries of preservation and archaeological recovery.

The purpose of this paper is to present a series of discriminant functions for sexing the human adult mandible. The major concerns in formulating the functions are to maximize the percent correct classification, to eliminate the most frequently indeterminable measurements in the specific skeletal series used, and to facilitate practical application of the functions. Because the expression of sexual dimorphism is population specific (1, 12), however, this study pertains only to the prehistoric Lower Illinois Valley Indian population of approximately 100 B.C. to A.D. 1300. The results obtained here, therefore, cannot be directly extrapolated to spatially, temporally, and/or genetically distinct populations. The basic approach, on the other hand, may be applicable in many situations where sex determination is desirable.

Materials and Methods

A sample of 172 individuals, 88 males and 84 females, was selected from the Lower Illinois Valley prehistoric Indian skeletal series housed at Indiana University, Bloomington. The bases for selection were minimal damage and disease, and an age at death assessment of 18 years or older for each individual. Four Lower Illinois Valley mortuary sites were represented: Schild, Koster, Pete Klunk and Yokem. The cultural periods involved were Middle Woodland (100 B.C. to A.D. 350), Late Woodland (A.D. 350 to A.D. 950) and Mississippian (A.D. 950 to A.D. 1300). The site-cultural period associations, and the age and sex distribution of the sample are summarized in Table 1.

TABLE 1. *Summary of the Sample*

		age (Todd's phases)									
Site-Cultural Period	Sex	I	II	III	IV	V	VI	VII	VIII	IX	X
Schild Late Woodland	male	–	–	–	–	–	2	–	2	1	–
	female	–	–	1	–	1	–	2	–	–	2
Schild Mississippian	male	2	–	–	2	1	4	3	2	1	1
	female	3	–	–	–	1	–	1	1	–	1
Koster Late Woodland	male	1	2	–	1	4	5	2	4	–	–
	female	–	–	–	–	1	1	–	1	2	–
P. Klunk Middle Woodland	male	1	1	–	4	3	4	9	–	2	2
	female	6	2	4	–	1	5	2	2	4	3
P. Klunk Late Woodland	male	–	–	–	–	–	–	1	–	–	–
	female	–	1	1	–	1	–	1	–	1	–
Yokem Late Woodland	male	1	1	1	1	1	–	1	–	–	–
	female	1	–	–	–	1	–	1	3	1	2
Yokem Mississippian	male	1	1	1	–	–	–	–	–	–	–
	female	2	–	–	1	1	–	2	–	–	–

The original sex assessment was based upon gross morphological indicators of the pelvis (14, 21). The age assessment was made using Todd's phases of the public symphyseal face (14, 21). In the case of individuals scored as younger than 20 years by Todd's phases, the age was verified by reference to the iliac crest, which fuses between 17 and 20 years of age (14). All sex and age determinations were made by the author. Comparison of the author's determinations with those recorded on the Indiana University inventories showed 94% agreement for sex and 85% agreement for age. Comparison of the author's original determinations with the reassessment of a random sample of 25 individuals showed 100% agreement for sex and 84% exact agreement for age, with the remaining 16% of the age determinations falling within one Todd phase of the original assessment.

The mandibular measurements were developed with reference to Morant (15) and Giles (10), in an attempt to describe mandibular size and shape. The majority of measurements were taken with a vernier dial calipers; breadth at ascending rami (BAR) was measured with a spreading calipers, and corpus length (CL) required a mandibulometer. Measurements were recorded in centimeters, and were read to the nearest 0.01 cm for the dial calipers and to the nearest 0.1 cm for the spreading calipers and the mandibulometer. Descriptions of the measurements are listed in the appendix. Unilateral measurements were taken on the left side, except where damage made the measurement questionable or impossible. In this case, the right side was substituted for the left.

Pearson product-moment correlation coefficients were calculated between two different measurement episodes of a random sample (N = 25) drawn from the original sample of 172 mandibles to test for measurement error. All 12 correlation coefficients were significant at $p = 0.001$; in addition, the slopes for the 12 measurements all approach one. Measurement error, therefore, is not a complication in the analyses.

A series of Student's t-tests were conducted on the measurements between sites and between cultural periods, separately for males and females, to determine whether the sample could be treated as part of a single, continuous population. Of a total of 216 t-tests, 4% were significant; this was less than the 5% expected due to

random chance. Treating the sample as derived from a temporally and spatially continuous population was, therefore, appropriate.

Student's t-tests were also conducted on the measurements between the sexes to determine which measurements differed significantly between the sexes at a univariate level. All measurements except mandibular body thickness (MBT) had t-values significant at $p = 0.001$. These results implied that sexual dimorphism was a size phenomenon in this sample of mandibles.

Stepwise discriminant functions were formulated using an SPSS DISCRIMINANT program with an F of 0.01 to enter and an F of 0.005 to delete (17). The functions were designed to maximize the Mahalanobis distance (D^2) between groups, in this case between males and females, by weighting and linearly combining collections of variables. The objective was to produce satisfactory discrimination between the sexes with a few functions (combinations of discriminating variables) as possible. One analysis began with the total set of 12 measurements; the remainder began with various combinations of one to six measurements. The various combinations were developed by first grouping the measurements into mandibular breadths (BB, BAR, BMF), lengths (CL, MPC) and heights (SH, HC, HP1, HP2, HM1, HM2), and then taking each of these groups as a variable set for analysis. One or two measurements from each of these groups was also combined to form a variable set, and, in the case of heights, one or two measurements from the other groups were added to as many as four heights. Only the analyses correctly classifying more than 80% of the sample used in function formulation, i.e., the base sample of 66 males and 66 females (N = 132), and more than 70% of a random sample not used in function formulation, i.e., the check cases of 22 males and 18 females (N = 40), will be presented.

Discussion of Results

All of the functions had significant Mahalanobis D^2s. The significance of D^2 was determined by the F value of the final step of each analysis. All final F values for the analyses were significant at $p = 0.05$. Of the total of 44 functions, 28 correctly classified more than 80% (range, 81-86%) of the base sample. Of these 28 functions, however, only seven correctly classified more than 70% of the check cases. The percent correct classification as either male or female of the base sample and check cases, the standardized and unstandardized discriminant function coefficients, and the group centroids for each of the seven functions are presented in Table 2. Figure 1 depicts the standardized discriminant score distribution and male/female sectioning point for each sexing function.

In discussing the results, we should keep in mind that there is greater variability in the expression of sexual characteristics in the skelton than in soft tissue (3). We assume that age and sex were phenotypically expressed in the archaeological skeletons. Several studies of sex determination of known sex and age skeletal material, however, evidence that such assumptions are far from unwarranted (2, 5, 7, 8, 9, 10, 11, 13, 18, 19, 22, 23).

The accuracy of sex determination in this study indicates that certain aspects of the mandible are sexually dimorphic. The male mean is greater than the female mean for each measurement, and these differences are significant at $p = 0.001$ for 11 of the 12 measurement t-values, suggesting that this dimorphism is largely, if not entirely, a size phenomenon; i.e., male mandibles are significantly larger than female mandibles in all respects, considered, except MBT. Certain variables, however, can be singled out as large contributors to the observed sexual dimor-

TABLE 2. *Mandibular Sexing Function Formulae*

		Discriminant Function Coefficients		Group Centroids		% Correct Classification	
Function	Measurements	Standardized / Unstandardized		Male / Female		Base Sample / Check Cases	
1	BB	-0.790	-1.012	-1.129	0.855	86%	78%
	BAR	0.349	0.576				
	MBT	0.380	2.453				
	BMF	0.104	0.403				
	MPC	-0.898	-6.748				
	SH	-0.556	-1.644				
	CL	-0.367	-0.816				
	HC	0.692	2.463				
	HP1	-0.822	-2.951				
	HP2	0.513	1.948				
	HM1	0.828	2.810				
	HM2	-0.957	-3.400				
	Constant	—	25.928				
2	BB	-0.428	-0.549	-0.948	0.718	83%	72%
	MPC	-0.950	-7.144				
	SH	-0.276	-0.818				
	Constant	—	24.741				
3	BB	0.469	-0.601	-0.927	0.702	83%	72%
	MPC	-0.975	-7.327				
	HC	-0.155	-0.551				
	Constant	—	24.548				
4	BB	-0.418	-0.536	-0.950	0.720	84%	72%
	MPC	-0.950	-7.140				
	HP1	-0.286	-1.028				
	Constant	—	24.942				
5	BB	0.403	0.517	0.959	-0.726	81%	72%
	MPC	0.974	7.323				
	SH	0.470	1.392				
	HC	-0.328	-1.168				
	HP2	0.105	0.399				
	Constant	—	-24.450				
6	BB	-0.399	-0.512	-0.992	0.752	81%	72%
	MPA	-0.989	-7.430				
	SH	-0.524	-1.551				
	HC	0.603	2.145				
	HP1	-0.787	-2.825				
	HP2	0.446	1.693				
	Constant	—	24.464				
7	BB	-0.445	-0.570	-0.963	0.729	86%	78%
	MPC	-0.949	-7.134				
	SH	-0.250	-0.741				
	HP1	-0.475	-1.706				
	HP2	0.435	1.653				
	Constant	—	24.831				

phism. On the basis of the standardized discriminant function coefficients, whose absolute values represent the relative contribution of each variable to discrimination, it appears that MPC is an extremely important aspect of mandibular sexual dimorphism, at least relative to the other measurements considered. In addition, the values of HC and HP1 suggest that this area of the mandible is also sexually dimorphic. The fact that the canine tooth tends to be the most sexually dimorphic tooth in humans (16), and the fact that the first premolar appears to be associated

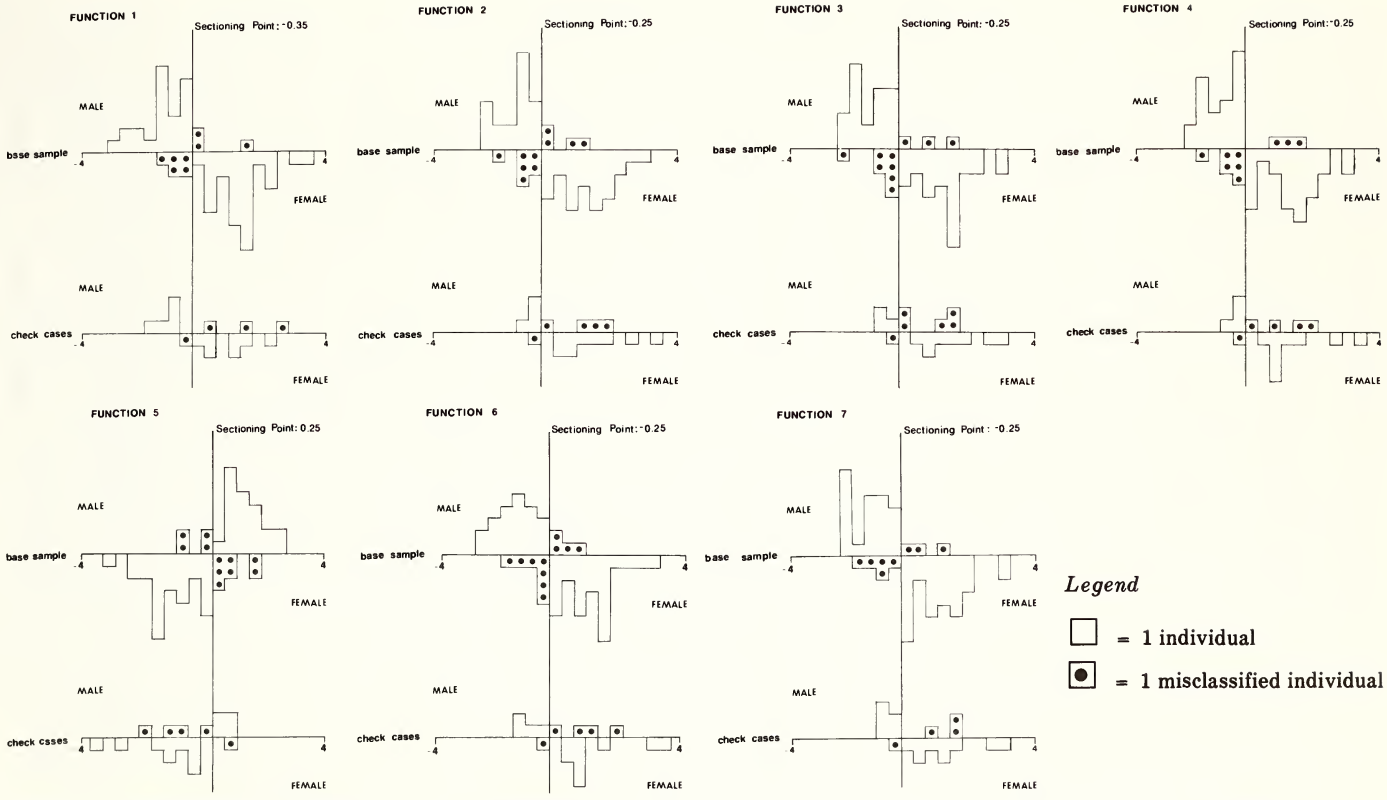

FIGURE 1. *Standardized Discriminant Score Distributions for the Base Sample and Check Cases of each of the Seven Functions.*

with the canine in a developmental tooth "field" (6) may have some bearing on future analysis of mandibular sexual dimorphism.

To apply the sexing functions, each measurement is multipled by the appropriate discriminant function coefficient from Table 2, and the products are added or subtracted according to their signs. The final score is then compared to the score distribution for the specific function (Figure 1), and the individual is assigned a sex according to the side of the sectioning point upon which the score falls. The distributions depicted in this paper are based upon the standardized coefficients. Sexing of individuals from outside the prehistoric Lower Illinois Valley will entail recalculation of at least the sectioning points, and probably recalculation of the sexing functions.

The functions presented here are not practical for sexing rather complete individuals, since other bones (e.g., the innominate) are more quickly and more accurately sexed by observation. The functions, however, are useful for sexing incomplete and/or damaged skeletons, and may be helpful in clarifying cases where other sexing methods have yielded ambiguous results. Unfortunately, individuals possessing only one half of a measureable mandible must be eliminated from the analysis because of the requirements of BB because all useful equations contain breadth measures. Since per cent correct classification as either male or female does not differ greatly between the functions, using the functions based upon three variables probably will not affect the results, and will make this method less time-consuming and more workable. There are, however, three possible sources of complications which must be realized. First, the sample used to formulate the functions excludes all individuals exhibiting obvious disease and/or ante-mortem tooth loss. Tooth loss and disease play a large role in craniofacial changes due to resorption and remodeling of bone. Thus, attempts to sex pathologic and edentulous individuals by these functions will probably yield spurious results. Secondly, the functions are formulated on a sample largely composed of middle-aged individuals (30-40 years old). There may be age effects or changes, possibly lined with continuing growth, disease and tooth loss, such that young and old adults will tend to be misclassified by the sexing functions. Finally, these functions are only directly applicable to prehistoric Lower Illinois Valley Indians. Other populations may exhibit aspects of mandibular sexual dimorphism, but they may differ in degree and/or kind.

APPENDIX. Description of Mandibular Measurements

1. Bicondylar Breadth (BB): The maximum breadth between the mandibular condyles proper, excluding excrescences commonly found in the region of the condylar neck, and taken from and to the lateral edges of the condyles. This measurement is the unmodified equivalent of Morant's W1 (15).

2. Breadth at Ascending Rami (BAR): The breadth between the ascending rami, taken from and to the lateral surfaces just external to the lingula mandibulae and perpendicular to the vertical axis of the mandible. The posterior margins of the mandibular foramina are appropriate substitutes in individuals who lack ligulae. This measurement was developed by the author.

3. Mandibular Body Thickness (MBT): The thickness of the mandible, taken at the midpoint of the cavity for the second molar, parallel to the vertical axis of the mandible. This measurement is modified from Giles (10), who takes it at the level of the second molar, but fails to specify where along that area the measurement is to be taken.

4. Breadth at Mental Foramina (BMF): The breadth of the mandible, taken

from the most anterior margins of the mental foramina, perpendicular to the vertical axis of the mandible. If the individual has more than one foramen per side, the largest is chosen for measurement. In the case where size differences are not discernable, the most anterior foramen of the group is used. BMF is equivalent to Morant's ZZ (15), but with the added specification of a plane for the measurement.

5. Molar-Premolar Chord (MPC): The length of the mandibular body, extending from the second molar anteriorly to the second premolar of the same side. The measurement is taken in line with the midpoints of the cavities for the respective teeth on the external surface of the mandible. MPC is similar to Morant's M2P1 (15), except that Morant measured anteriorly to the first, rather than to the second, premolar. The present author chose the second premolar because of the great variability in repeated readings caused by mandibular curvature when the measurement was extended to the first premolar.

6. Symphyseal Height (SH): The height of the mandibular symphysis, measured from the infradentale to the most inferior point on the anterior surface of the symphysis in the midline. This measurement is modified from both Morant (15) and Giles (10), the inferior reference point (defined as the lowest median point on the lower border of the mandible by these authors) being redefined as the lowest median point on the anterior surface of the bone. This modification was made because of the large number of protuberances observed on the lower border of the mandible, which created uncertainty in measurement.

7. Corpus Length (CL): The maximum length of the mandible resting in standard horizontal plane (15), from the most anterior point on menton to the posterior surface or both condyles. "Rockers" may be fixed in standard horizontal plane by a small piece of plasticine. CL is equivalent to Morant's CpL (15), except for the inclusion of both condyles as the posterior reference point.

The following measurements describe the height of the mandibular body, measured on the external surface in line with the midpoint of the cavity of each respective tooth. The superior limit of the measurement is the superior border of the alveolus; the inferior limit is the most inferior point on the external surface. The measurement is taken parallel to the vertical axis of the mandible. Height at second molar is equivalent to Morant's M2H (15); the other heights were developed by the author.

8. Height at Canine (HC).
9. Height at First Premolar (HP1).
10. Height at Second Premolar (HP2).
11. Height at First Molar (HM1).
12. Height at Second Molar (HM2).

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Sexing the Human Sternum: Archeological Applications

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The adult human sternum shows size differences related to both an individual's sex and age. Ashley (1956) using measurements of sternal length, width, and two ratios was able to discriminate between the sexes in a European and an East African population. He found that the absolute measurements varied with sex, irrespective of body height, and that continuing growth throughout adulthood slightly modified the value of any discrimination rule based on such measurements.

Jit, Jhingan, and Kulkarni (1980) applied Ashley's techniques to a North Indian population, but did not consider age except to use specimens over age 18. They also used multivariate analysis for discrimination in their sample. Their study claimed accurate in sex determination for 72.12% of the males and 62.50% of the females using Ashley's techniques, and 85% accuracy using mutivariate analysis of their sample (1980: 217). Ashley's study claimed 80% overall correct application of his discrimination rules (1956: 42).

These findings, then, form the basis of this paper. Utilizing both absolute measurements and ratios after Ashley (1956) and multivariate analysis after Jit, *et al* (1980), the following questions were addressed. Can these techniques be applied to archeological remains, including incomplete sterna, and how much of the resulting inaccuracy can be accounted for by age effects or abnormalities in individual sterna, for example fractures?

Materials

The present study utilized archeological materials recovered from two central Illinois mortuary sites: the Schild site, Greene County, and the Pete Klunk site, Calhoun County. Both sites were multi-component sites; Schild having Late Woodland and Mississippian mounds, and Klunk with Middle, Late Woodland, and one Archaic mound. Seventy-five Schild Mississippian and 61 Klunk Middle Woodland sterna, 136 total, were chosen for analysis because these components were better preserved than either Later Woodland component. Radiocarbon dates for these occupations are A.D. 175 ± 75 for Klunk Middle Woodland (Perino 1968:115) and A.D. 943-1194 ± 114 for Schild Mississippian (Droessler 1979:57).

Biological continuity has been demonstrated in this region (Buikstra 1977; Droessler 1979). Thus the Schild and Klunk materials used in this study can be considered to be genetically related.

Methods

The 136 sterna selected were divided into two groups: those sterna that were complete (manubrium and mesosternum) and those that were broken or had either the manubrium or mesosternum missing.

Measurements were taken in millimeters on the manubrium and mesosternum, excluding the xiphoid process, as shown in figure 1. The measurements are as follows:

M = manubrial length in midline (variable X1)
B = mesosternal length in midline (variable X2)
S_1 = width of first sternebra (variable X4)
S_3 = width of third sternebra (variable X5)

From these the following values were computed:

M + B = total manubrial-mesosternal length (variable X3)
M × 100/B = manubrium-corpus index (variable X6).
$S_1 \times 100/S_3$ = sternal width index (variable X7)

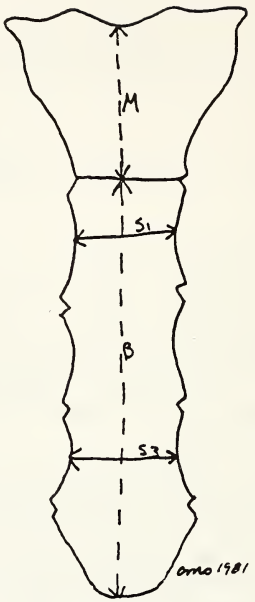

FIGURE 1

After the values were obtained, those from sample one (complete sterna, 75 in all) were subjected to statistical tests, computing mean and standard deviation for each variable category by sex. An F-test was run for each variable to determine if the differences between the means were significant, and 21 linear discriminant functions were generated.

Individual measurements were graphed using bar diagrams (see Figure 2), in which the measurements are given along the abscissa and the number of cases along the ordinate. From the graphs, cut off points were determined for assigning specimens to either the male or female group.

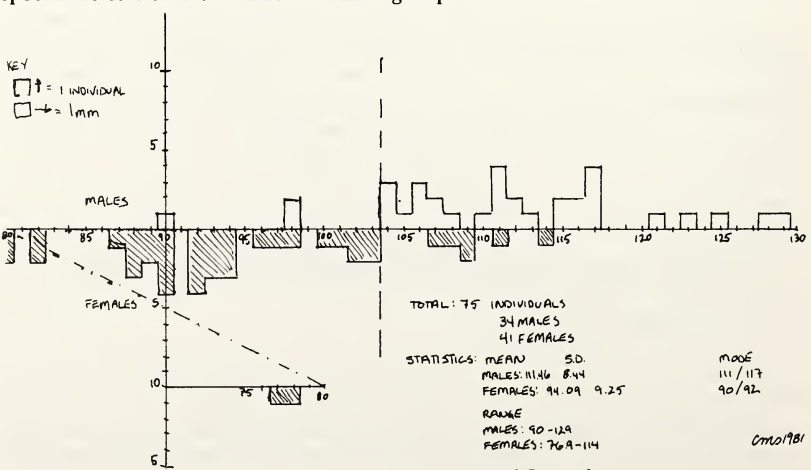

FIGURE 2: *Graph of Mesosternal Length*

After the statistical and graphic analyses were performed on sample 1, those sterna with incomplete measurements were analyzed using the graphic cut-offs and 12 of the 21 discriminant functions, chosen for their applicability and high accuracy. Applicability is here defined as including variables present in incomplete specimens. Those functions with over 70% accuracy were used, an arbitrary level of accuracy, in order to utilize as many possible combinations of variables in the sample of incomplete sterna.

Results: *Univariate Differences.*

A significance test (F-ratio) was run on the means of each measurement for the two groups. The means of the first six variables were found to differ significantly between the sexes. Variable X7: sternal width index was not found to have a significant difference in the group means.

Graphic Analysis

The following is a summary table of the results of graphic analysis:

Variable	Means	Standard Deviation	Cut-off	Accuracy Sample 1	Range Sample 1	Accuracy Sample 2
X1	M 49.84 F 45.00	5.00 4.56	46.5	ALL 72 % M 76 % F 68 %	36.8 - 67.5	59%
X2	111.46 94.09	8.44 9.25	103.5	88 % 99.9% 85 %	76.9 - 129.0	78%
X3	161.29 139.04	9.45 11.08	151.0	85 % 85 % 85 %	115.3- 178.9	67%
X4	27.89 23.92	3.38 2.61	26.5	73 % 59 % 85 %	19.7- 35.0	61%
X5	34.76 29.83	6.17 4.45	30.0	70.5% 85 % 56 %	22- 49	63%
X6	45 % 48.19%	6.00 6.08	47.5%	63 % 74 % 56 %	35.49%- 62 %	89%
X7	81.66% 81.46%	11.91 12.76	None	– –	59.92%- 131.82%	–

Overall, the results of graphic analysis in the determination of sex reflects the significance of the mean differences for each variable. The length measures (X1-3) are better discriminators than width measures; the ratios are the least useful. While the mesosternal length is the best of the variables to use, it is often broken post-mortem; this reduces its practicality. In the second sample, only 27 of 61 cases had a measureable mesosternum (44%). Variable X3, total sternal length, is also a good indicator, but since it is dependent on the presence of *both* the manubrium and mesosternum, its usefulness is limited despite its accuracy. The manubrial length, although not as accurate as these, is also useful, as it is often the only part of the sternum recovered. In sample two, 26% of the cases were single manubria.

Viewing the results, we see that the size of the mesosternum has a greater relationship to an individual's sex than does the size of manubrium.

The width measures, X4 and X5, show an extreme overlap in their distributions. The width of the first sternebra showed a high F-ratio; however, this significance was not borne out by the actual distribution. Both these can be useful when the mesosternum is broken.

Variable X6, the manubrium-corpus index, was used by Ashley to test the accuracy of Hyrtl's law, which asserts that if the relationship of manubrial length to mesosternal length is greater than 1:2 the sternum is female; if less, it is male. In this population the relationship was found to be somewhat less (47.7% instead of 50%). The index, like the total sternal length, is dependent upon the both the manubrium and mesosternum, and is not as accurate in classifying sterna as to sex as are the other measures.

Variable X7, the sternal width index, represents a measure of Paterson's female type sternum, that is, relatively broad at its lower portion (following Ashley 1956). If the sternum is relatively wide at its lower end, then the ratio wil be relatively small, and therefore female (1956: 34). Both in this and in Ashley's study, however, it was found that the ranges were nearly identical and that the means differed by small percentages. Consequently no cut-off was determined and the usefulness of this variable is slight.

Linear Discriminant Function Analysis

Twenty-one linear discriminant functions were generated using the preceeding seven variables and run on the cases with complete sterna (sample 1). Included in these were seven using only the single variables, to compare with graphic analysis. The range of accuracy obtained by all twenty-one functions was 56-90.7%. Twelve of these could be applied to the sample of incomplete sterna, with accuracies of 90.7-72%. The following is a summary table of the results of this analysis:

Function	Variables Used	Accuracy	Use With Sample 2 (accuracy)	Compare With Graphic Analysis
1	X2, X3, X4, X7	90.7%	–	–
2	X1, X2, X3, X6	85.5%	50 %	–
3	X2, X4, X7	88 %	82 %	–
4	X4, X5, X7	72 %	56 %	–
5	X1, X2, X4, X5	90.7%	–	–
6	X3, X6, X7	85.3%	–	–
7	X2, X4	86 %	83 %	–
8	X3, X5, X6	89.3%	100 %	–
9	X1, X4, X5	76 %	62.5%	–
10	X1, X5, X6	89.3%	100 %	–
11	X1	69.3%	–	72 %
12	X2	86.7%	70.4%	88 %
13	X3	85.3%	–	85 %
14	X4	72 %	–	73 %
15	X5	61.3%	–	70.5%
16	X6	62.7%	–	63 %
17	X7	56 %	–	–
18	X1, X4	77.3%	70 %	–
19	X1, X5	73.3%	60 %	–
20	X2, X4, X5	88 %	83 %	–
21	X1, X2	85.3%	66 %	–

Summary

Discriminant function analysis is extemely helpful in the determination of sex using combinations of sternal measures.

Sample 1, with all measures present and age and sex known was used to establish the classificatory scheme using discriminant scores. The incomplete specimens (Sample 2) were used to independently test the accuracy of classification.

The functions (2, 3, 4, 7, 8, 9, 10, 12, 18, 19, 20, 21) were applied to the second sample using a program that computed the discriminant scores for only those cases fitting the conditions. Conditions were specified such that if a particular variable did not equal zero, certain equations were used to calculate discriminant scores. Coefficients of the equations were derived in the discriminant analysis of Sample 1.

Functions 11-17 were generated using each variable singly in order to compare the accuracy of this technique to that of graphic analysis, where only one measurement is available. It was found that in this circumstance, graphic analysis is more accurate (or as accurate), and is recommended.

The resultant scores were compared to the distribution of scores in the first sample and sex determinations were made accordingly. Only sixteen of the sixty-one cases in sample two were misclassified according to the twelve functions, (26%). Percent accurate values for this limited set of specimens generally reflect the accuracy seen in the original sample, although some categories are too small to provide meaningful estimates of accuracy of classification.

Misclassifications

The secondary question of this study was to account for any misclassifications. First, the factor of age was considered. Ashley's study found that there was a 2-3% increase in four of the five measurements with increasing age (Ashley 1956:33). With this in mind, the following question was asked: Were the misclassified females older (over 40) and the misclassified males younger (aged 20-30)? A tally of the misclassified sterna shows that 47 out of 136 (total sample: 34.6%) were misclassified, with 23 of these being most likely due to to age (48.9%). Twelve (52%) of these were females aged 40 or more, and eleven (48%) were males in this 20-30 year age bracket, six of them under twenty-five.

Other factors considered were: presence of extra sternebrae in the mesosternum, a shallow or the absence of the jugular notch, and assymetry of either the manubrium or the mesosternum, which would affect the measuring process as well as the measurements, and fractures or other pathologies.

Table of Misclassifications

Factor:	Percentage (of 47):
Age	48.9%
# of sternebrae	
extra	2.1% (one female aged 45-50)
less	(one, male aged 20-24)
jugular notch, absent or shallow	12.7% (two females aged 50 +)
assymetry	25 % (3 males aged 20-30, 3 females 45 +)
fracture	2.1% (one female 50 +) (one, male 20-24, Cleft mesosternum)

Summary and Conclusions

To summarize, then, this study applied a set of graphic and statistical techniques for sex determination to a sample of sterna collected from two genetically related aboriginal populations from the Lower Illinois River Valley. The hypothesis of a sex-related difference in sternal size was confirmed. Discriminant function analysis and univarate analysis were used to assign individual sterna to either sex on the basis of various measurements and ratios. Overall, 47 of 136 sterna were misclassified (65.4% correct), but the accuracy of individual methods ranged from 90.7 to 56%. If only a single measurement is present, then graphic analysis is preferred as it yields a higher accuracy of classification than does discriminant function analysis. Age was found to have a significant effect as well, and accounts for the bulk of the misassigned sterna; females over ages 40 tend to be classed as males and males under age 30 tend to be classed as females.

Application to Archeological Data

The techniques presented in Ashley (1956) and Jit *et al* (1980) are applicable to archeological data, as demonstrated here. The cut off values of graphic analysis and discriminant scores will vary with populations, but the basic techniques are valid. Following the methodology of this study, the classification scheme should be set up with a sample of complete sterna of know sex and age. Then measurements from incomplete or isolated sterna can be plugged in and analysed.

The results of this classification can be useful in many ways, specifically in confirming sex of individuals whose classification is unclear using other techniques, possible association of isolated sterna with other skeletal remains, analysis of cremated materials, and obtaining more accurate assessments of demography.

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BOTANY

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ABSTRACTS

Potassium Dependence in Chlamydomonas reinhardi: Evidence for a transport Mutant. DOUGLAS D. DOCTOR and L. DAVID POLLEY, Crawfordsville, Indiana 47933.——The analysis of transport mutants in bacteria and fungi has provided considerable insight into the regulation and the molecular mechanisms of transport in those organisms. Despite the successes of this approach, genetic analysis of transport has not been undertaken in algae or higher plants. Here, we report the results of our initial efforts to isolate and to characterize mutants of *Chlamydomonas* defective for potassium transport.

Wild type cells of *Chlamydomonas* (R3 + NM) were mutagenized by ultraviolet irradiation, Survivors (approximately 5%) were plated on a modification of TAP medium, TAPM-4, containing 10 mM potassium. Surviving colonies were picked and screened indiscriminately by replica-plating to TAPM-4 containing only a trace amount of potassium. Out of approximately 3,000 colonies screened, two did not grow on the low potassium plates. These were selected as putative potassium transport mutants and one of them, laboratory strain NM1/92/22, was selected for further comparative studies with the wild type strain.

The transport of potassium by strains R3 + NM and NM1/92/22 was characterized by following the uptake of ^{86}Rb. Rubidium has been shown to be a suitable analog of potassium and its radioisotope has a more convenient half-life than does ^{42}K. Our studies show that rubidium uptake is energy dependent and that it is not inhibited by ouabain. In contrast to higher plants and algae which generally have complex transport kinetics, Rb transport in *Chlamydomonas* demonstrates simple Michaelis-Menten kinetics. A V_{max} of 28 nmoles Rb/hr/10^6 cells and a K_m of 0.8 mM were determined for Rb uptake by R3 + NM cells grown in TAPM−4 medium containing 10 mM K. When these cells were grown under potassium stress conditions, i.e. 0.01 mM K, or when cells were downshifted from 10 mM K to 0 mM K and incubated for 24 hours, the V_{max} increased 5-fold to 140 nmoles Rb/hr/10^6 cells, but there was little change in the affinity for Rb, K_m = 1 mM. The mutant exhibited slightly higher V_{max} of 40 nmoles Rb/hr/10^6 cells and a K_m of 0.8 mM. When these cells were downshifted, however, no change in the kinetic parameters was observed, V_{max} = 42 nmoles Rb/hr/10^6 cells and K_m = 1mM.

The observed shift in V_{max} may be the result of an allosteric change in the potassium pump, production of new pumps with increased capacity, or increased production in the number of pumps. The mutant is unable to increase the capacity of its potassium transport system. This defect may be, in part, the basis for its inability to grow in medium of low potassium concentration.

Growth and Extractable Carbohydrates of Red Oak Seedlings during the First Growing Season. D.S. EGEL and P.E. POPE, Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907.——There is considerable information concerning the seasonal distribution of carbohydrates in many tree species; however, little of this information relates to seedlings during the first growing season. Red Oak (*Quercus rubra* L.), an important species in hardwood regeneration, was used in this study to determine the methanol extractable carbohydrates from the time of seed germination through seedling dormancy during one growing season. After germination in a greenhouse, four week old seedlings were transferred to a growth chamber where day-night temperatures were from 83 to 71 F respectively and the day length was kept at 14 hours until dormancy when day-night temperatures were reduced gradually to 40 and 36 F respectively and day length reduced to eight hours. Seedlings were fertilized alternately with Hoaglands #2 and micronutrient solution at seven day intervals. Ten seedlings were harvested every two weeks during the 16 week growing period for a total of eight harvests plus an additional harvest after dormancy. Parameters determined include dry weight by component and of cotyledons, seedling height and diameter and methanol extractable carbohydrate by component as well as cotyledons. Percent carbohydrate in foliage exceeded that in either stem, or foliage for every harvest period. Stem carbohydrates decreased steadily until the last two harvests, after which percent carbohydrates increased. Root carbohydrates remained in the same range as stem carbohydrates, but varied more, decreasing possibly as a result of growth flushes. Beginning with the induction of dormancy, root carbohydrates increased and percent carbohydrates in the cotyledons decreased steadily over the growing period. Based on mean values obtained from each harvest period, stem height was inversely correlated with percent carbohydrates in the stem ($r = -0.81$).

Preliminary Light and Electron Microscope Studies of Laticifers in Stapelia bella (Asclepiadaceae). BERNICE B. ELLIS and KATHRYN J. WILSON, Department of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46223.——Both nonarticulated branched and articulated nonanastomosing laticifers have been reported by Shaffstein (1932) present side by side in stem tissues of *Stapelia bella*. However, at both the light and ultrastructural levels, only nonarticulated branched laticifers have been identified in shoots of this plant. The origin of the nonarticulated branched laticifer system has not been determined. The growing cell tips penetrate all parts of the mature plant and are highly branched and coenocytic. The ultrastructure of developing and mature nonarticulated laticifers was studied in nonsucculent floral meristems. The most conspicuous ultrastructural feature of developing cells is the numerous small vacuoles some of which appear to originate from dilating endoplasmic reticulum. No plasmodesmata are apparent in walls. Golgi bodies are numerous in both developing and mature cells and Golgi vesicles probably make a significant contribution to the vacuolar system. Plastids are agranal leucoplasts with some internal lamellae and plastoglobuli. Numerous mitochondria appear functional even in mature cells. The mature protoplast is osmotically sensitive and possesses a large central vacuole with peripheral cytoplasm. Electron dense latex particles appear first in small vacuoles in the peripheral cytoplasm of relatively immature laticifers and then the central vacuole of mature cells.

Structure and Development of the Glandular Secretory System in Staminate Inflorescences of Cannabis sativa (Cannabaceae). CHARLES T. HAMMOND, Saint

Meinrad College, and PAUL G. MAHLBERG, Indiana University, Bloomington, Indiana 47405.——The glandular secretory system of staminate plants of marihuana, like that of pistillate plants, consists of a variety of glandular hair types distributed over most of the plant surface with greatest abundance localized in flowering regions. The staminate glandular system differs from that of the pistillate system mainly in a reduced gland abundance and in a notable presence or absence of specific gland types. Two common types of glandular hairs found on staminate plants are bulbous and capitate-sessile types. These glands closely resemble their gland counterparts on pistillate plants, the former being small with a circular 20 um diam head on a few-celled axis and the latter with a large globose 40-50 um diam head also supported on a few-celled axis. Notably absent from staminate plants is the tall capitate-stalked gland type which characterizes the glandular complement of the pistillate infloresence. A unique gland type found on staminate plants and lacking on pistillate plants is the antherial-sessile gland. As this name suggests, this gland type is found only on anthers of the staminate plant. These glands develop synchronously on very young anthers attaining a full sized 100-120 um diam head just prior to anthesis. Frequently gland heads become oblong in shape accenting their large size in comparison with capitate-sessile glands on the surrounding sepals. Occasionally atypical forms of the antherial-sessile gland are found in which cells of the few-celled axis supporting the gland head elongate to produce a short stalk. This stalk, however, is not homologous to the stalk of the capitate-stalked gland type as the latter arises from proliferation of surrounding epidermal and hypodermal cells.

A Phytogeographic Analysis of Leaf Architectural Features of the Fagaceae. JAY H. JONES and BETH L. FRIEDBERG, Department of Biology, Indiana University, Bloomington, Indiana 47405.——The Fagaceae has been investigated frequently by phytogeographers. Yet, no one has explored the extent and nature of phytogeographic variation in leaf architecture within the family as a whole. In fact, a scan of the literature reveals few comprehensive studies of this type on any plant family. A wide range of leaf material was examined in several major herbaria. Over three hundred leaves were collected for further analysis. These represented all geographical regions in which members of this family are found. Leaf architecture was examined using methods described by Dilcher, Hickey and Wolfe. Major phytogeographic variation was found to be correlated with differences in the taxonomic composition of various areas. For example, species of the strictly northern hemispheric genus *Fagus* consistently possess regularly spaced simple teeth and secondary veins which are straight distally and outwardly bowed near the petiole. Species of the exclusively southern hemispheric genus *Nothofagus* on the other hand frequently possess doubly serrate margins with irregularly spaced teeth or have entire margins. It appears that different genera have reacted differently to similar environments. For example, north temperate members of the genus *Quercus* have developed a lobed margin whereas conspecific members of the genus *Fagus* possess only dentate margins. Intrageneric phytogeographic variation within this family also appears to be significant. Tropical species of *Quercus* are entire margined whereas the temperate *Quercus* species tend to have lobed margins. A similar trend is also found in *Nothofagus*. Here the temperate forms are usually toothed and the tropical forms are entire. There also is a relationship between leaf apex angle and geographical latitude. Tropical forms usually possess more strongly tapered leaf apices than do the temperate forms. Several even possess drip tips. These observations conform well to those obtained in the foliar analysis of entire floras with respect to latitude.

Variation of Foliar Features in the Rhamnaceae: Tribes Rhamneae and Zizypheae. JAY H. JONES, Department of Biology, Indiana University, Bloomington, Indiana 47405.——A survey of the Rhamnaceae has been undertaken in order to provide a basis for the analysis of fossil rhamnaceous leaf material and to explore the intrafamilial evolution of leaf forms. The leaf structure of the tribes Rhamneae and Zizypheae has been determined and is the subject of this report. Collectively, species of these tribes exhibit considerable ecological latitude. The leaves are correspondingly modified from needle-like leaves of some xerophytic species to typical lanceolate mesophytic forms. Like other Rhamnaceae, leaves of all plants in these tribes are simple and most have percurrent tertiaries which are perpendicular to the primary veins. A few possess reticulate tertiary venation. Entire margins are common and teeth when present are asymmetrical, small and irregularly spaced. Simple pinnate and acrodromous forms are found in both tribes. Among the simple pinnate forms eucamptodromous leaves predominate. A few brochidodromous forms exist however, again in both tribes. The presence of these and other characteristics in both tribes makes classifying leaves at the tribal level difficult. Variation in leaf form does not rigidly conform to accepted classification schemes based on reproductive material even though leaf form is species constant and useful in the identification of species or groups of species. Leaf form at the generic level is fairly consistent, however, and it is possible to assign isolated fossil leaves to specific genera or complexes of similar genera. The presence of strikingly similar leaf forms in both subfamilies suggests environmental selection from a common gene pool or, in some cases, flaws in current classification schemes.

The Gasteromycetes of Indiana. PHILIP A. ORPURT, Department of Biology, Manchester College, North Manchester, Indiana 46962.——The group of fungi known as the Gasteromycetes is considered to be among the most advanced forms. Their basidiospores are produced within a closed basidiocarp which may in some remain closed or in others does not open until the spores have matured and thus expose the fertile, spore-producing tissue known as the gleba. The Gasteromycetes are terrestrial occurring for the most part above the soil. Some may be subterranean and some occur on logs or on dung. The puffballs, the earthstars, the sclerodermas, the stinkhorns, and the bird's nest fungi are included within the group.

Relatively little effort has been made to collect and to catalogue species of Gasteromycetes for the state of Indiana since the early reports of L.M. Underwood in the 1890s. Underwood, who was the first Director for the Botanical Division of the Indiana State Biological Survey, reported the occurrence of 23 species of "puffballs" for the state in 1893. Additional species were subsequently added to the list by Underwood as well as by J.M. Van Hook for the Bloomington area (1911), by F.D. Kern for the Lafayette area (1912), by A.R. Bechtel for the Crawfordsville area (1939), and by J.O. Cottingham for Marion Co. (1948).

The writer has undertaken a compilation of the records of Gasteromycetes for the state of Indiana which will culminate in the development of an annotated list. An effort is underway to examine specimens of as many of the reported species as possible. Also, collections of fresh specimens of Gasteromycetes are being made.

Platanoid Fossils from the Dakota Formation: A Paleosystematic Problem. ROBERT N. SCHWARZWALDER, JR., and DAVID DILCHER, Department of Biology, Indiana University, Bloomington, Indiana 47405.——The flora of the mid-Cretaceous is of special interest to the angiosperm paleobotanist because it was at that time that many of the evolutionary lines ancestral to modern flowering plants arose. The Dakota formation of mid-Cretaceous age contains a number of fossil leaves

with a structural similarity to extant *Platanus* species. These leaf-forms have been termed "platanoid" by E. W. Berry in reference to their *Platanus*-like appearance, but they have been placed in several diverse modern genera as well as a few solely extinct ones. Our research on a population of platanoid fossil leaves representing one species from a mid-Cretaceous clay deposit has allowed us to determine that the Platanaceae had evolved by that time. An analysis of tooth anatomy and fine venation patterns along with a morphological investigation of leaves and associated infructescences were instrumental in our assessment of the species. Platanoid leaves from sandstone deposits of the same age are systematically problematic as they possess several of the same morphological features but, due to their tremendous variation in form, poor preservation and the rare occurrence of associated reproductive material, have proven difficult to ally with modern angiosperm taxa. These sandstone impressions, although preserving fewer anatomical details than similar compression fossils, are amenable to similar types of analysis. There are clear relationships of certain members of this platanoid complex to the extant Platanaceae. Other platanoid species appear to have been arbitrarily placed in the group based upon features of gross morphology and lack sufficient structural detail for taxonomic placement.

An Ultrastructural Study of Soybean Cultivars Differing in Response to Salt Stress. CAROL A. SINGLETON and ROBERT W. KECK, Department of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, IN 46223.——Two cultivars of soybean (*Glycine max* (L.) Merr.), "Lee" and "Jackson" were grown hydroponically under controlled conditions of temperature and light. After two weeks plants were treated either by adding 40 mM calcium chloride to the solution or kept as control plants without salt. Treatment caused severe chlorosis and death in the salt sensitive "Jackson" and little change in the salt tolerant "Lee". In both salt treated cultivars, apical root growth ceased and roots darkened in color. Roots were fixed for electron microscopy, and cortical cells examined for ultrastructural variation. The most notable difference between treated and control roots is the abundance of dilated endoplasmic reticulum in treated cells. Treated cells also possess a greater proliferation of small vacuoles and small vesicles of unknown origin than control cells. The mitochondria and other cell components appear normal in both treatments.

A Comprehensive Study of Select Stomatal Complex Features in the Fagaceae. STEVEN L. STIER and JAY H. JONES, Department of Biology, Indiana University, Bloomington, Indiana 47405.——Stomatal length, width, guard cell width, stomatal complex type and the number of accessory cells were examined in leaves of the Fagaceae. Approximately 348 specimens representing 275 species, all 8 genera and all 3 subfamilies were collected from major herbaria. Isolated cuticles were prepared and examined with the light microscope. All specimens examined possessed anomocytic stomatal complexes. This feature is consistent within the Fagaceae and should be useful in the determination of fossil materials. The number of adjacent epidermal cells varied from 4 to 12 with familial, subfamilial and generic averages of 7. The generic and subfamilial ranges in stomatal length, stomatal width, and guard cell width overlapped considerably. Thus, the use of these features in the intrafamilial classification of fossil fagaceous leaves is not recommended. Significant differences were found in some cases, however, when generic means were compared. For example, *Fagus* species collectively have smaller stomata than those of *Nothofagus*, *Lithocarpus* and other genera. Although these and other statistically significant differences are of interest, they are not very useful for the classification of specific fossil leaf types.

A Critical Analysis of the Nature and Taxonomic Distribution of Foliar Trichomes in the Fagaceae. MARK WASSERMAN and JAY H. JONES, Department of Biology, Indiana University, Bloomington, Indiana 47405.——Taxonomic classification of fossil leaf remains has posed serious problems in the past due to a lack of information about the foliar characteristics of the Fagaceae. It is hoped that data gained in this study will provide a basis for the analysis of fossil material with probable fagaceous affinities. Trichome morphology and distribution has been surveyed in all 8 extant genera of this family. Over 300 specimens were collected from several major herbaria and systematically examined, using transmission light microscopy of cuticle preparations, epiillumination light microscopy of whole leaves and scanning electron microscopy. A wide range of trichome types was found to occur within this family. Identification of the leaves at the generic level appears to be possible. Laterally fused tufts can even be used to distinguish *Lithocarpus* species from the nearly identical *Castanopsis* species. The genus *Nothofagus* can be determined by the presence of large glandular trichomes. *Fagus* is characterized by the uniform presence of uniseriate multicellular trichomes and unicellular simple hairs. Of particular interest is the presence of a unique trichome complement in *Castanopsis chrysophylla* and *Castanopsis sempervirens* which set these species apart from other members of this genus. This seems to support the segregation of these species into the genus *Chrysolepis* as suggested by Hjelmquist. Work is continuing on the Quercoideae in order to elucidate phytogeographic and infrageneric differences in trichome complements.

Accumulation and Distribution of a Single Dose of ^{59}Fe in Wheat and Soybeans. CONNIE M. WEAVER, Purdue University, West Lafayette, Indiana 47907.——Accumulation of iron by edible parts of staple crops such as wheat and soybeans influences the dietary contribution of these foods. However, much of the total iron content of plant foods may not be available for human nutrition because plant seeds contain relatively high concentrations of phytate and fiber which have been associated with the binding of micronutrients. In order to accurately reflect the bioavailability of trace elements from specific foods, the approach of intrinsically labeling foods with the element of interest is used. This study investigated the efficiency of incorporating a single dose of ^{59}Fe into the edible portions of hydroponically-grown wheat and soybeans when added as a sequestered or unsequestered iron source and when added during the vegetative or reproductive phase of the plant growth cycle. For both plant species, more ^{59}Fe was accumulated by the edible plant parts when added in an unsequestered form during the vegetative period of the plant growth cycle. For wheat, 9.2% of the ^{59}Fe dose was accumulated in the mature grain and 27.4% of the dose was accumulated by soybean cotyledons. This information can be used to determine optimal conditions for efficiently labeling plants for further bioavailability studies.

Method and Duration of Weed Control Affect Survival, Height and Diameter of Planted Black Walnut. ROBERT D. WILLIAMS, North Central Forest Experiment Station, Forest Service, USDA, Bedford, Indiana 47421——Fourteen year results from a weed control study established in 1967 on Pierson-Hollowell property near Martinsville, Indiana, show that differences in height and diameter are attributable to both method of weed control and number of years weeds were controlled after planting. Trees treated with simazine were taller and larger in diameter than trees treated with atrazine which were larger than those in cultivated plots. Trees in plots treated 3 years were taller and larger in diameter than trees treated 2 years which were larger than those treated only 1 year. Weed control method

resulted in differences in survival. Survival was lowest in the cultivated plots and best in the plots treated with simazine.

Ruthenium Complexes as Electron Acceptors in Photosystem I of Spinach Chloroplasts

R. Barr and F. L. Crane, Purdue University, West Lafayette, Indiana 47907

and

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Abbreviations used: DBMIB-2,5-dibromo-3-methyl-6-isopropyl-p-benzoquinone; DCMU-3-(3,4-dichlorophenyl)-1, 1-dimethylurea; MV — methylviologen; PS II — photosystem II; PS I — photosystem I; Ru red-ruthenium red; SM — silicomolybdic acid.

Introduction

Ruthenium red is a polymucosaccharide stain, which has been used in mitochondria as a specific inhibitor of Ca^{2+} transport (9, 10). The molecular complex of ruthenium red has been studied by Clausen (7). The crystal structure of the ethylenediamine analog of ruthenium red is shown by Smith *et al.* (13). The reduction of acido ruthenium(III) ammine complexes by various cellular components has been studied by Clarke and associates (5, 6) and as acceptors for NADH dehydrogenases of plasma membrane by Laliberte, Crane and Clarke (8). In this study we have compared the positively-charged ruthenium ammine complexes with the negatively-charged methylviologen as electron acceptors in PS I with the purpose of finding out how local surface charges affect electron transport.

Materials and Methods

Spinach chloroplasts were prepared and assayed as previously described (3). The isolation and suspension medium was 0.4 M sucrose and 0.05 M NaCl (SN chloroplasts). Chlorophyll concentrations were determined according to Arnon (1). Oxygen uptake with methylviologen or oxygen evolution with the ruthenium ammine complexes as electron acceptors was measured with a Clark-type electrode. Reaction rates were recorded with a Sargent-Welch SRG recorder. The ruthenium ammine complexes were synthesized by Dr. Clarke and associates of Boston College with the exception of hexaamine Ru(III) chloride, which was purchased from Alfa Inorganics and further purified by precipitation and recrystalization from 0.1 M HCl. Ruthenium red was purchased from K and K Laboratories, Inc.

Results and Discussion

It was found that chloroplasts vary in their ability to reduce ruthenium ammine complexes and ruthenium red. Figure 1 shows that ruthenium red and chloropentaammine ruthenium(III) gave the lowest electron transport rates in spinach chloroplasts, while the pyridine pentaammine ruthenium complex, which is not as readily autooxidizable, gave the highest rates, comparable to those obtained with methylviologen as the electron acceptor. The differences in rates are also due to reduction potentials of the various Ru(III) complexes and the ability to reach the sites of action in the membrane. The pyridine complex has been shown to penetrate into proteins on account of the pyridine ring (10), thus establishing a closer contact with the active site on the membrane. The optimum pH for all these reactions is between pH 7 and 7.5 (Figure 2).

Since ruthenium compounds have not been used as electron acceptors in

spinach chloroplasts before, it was necessary to establish, if the $H_2O \rightarrow$ MV reaction and the $H_2O \rightarrow$ ruthenium(III) ammine complexes behaved alike toward various PS

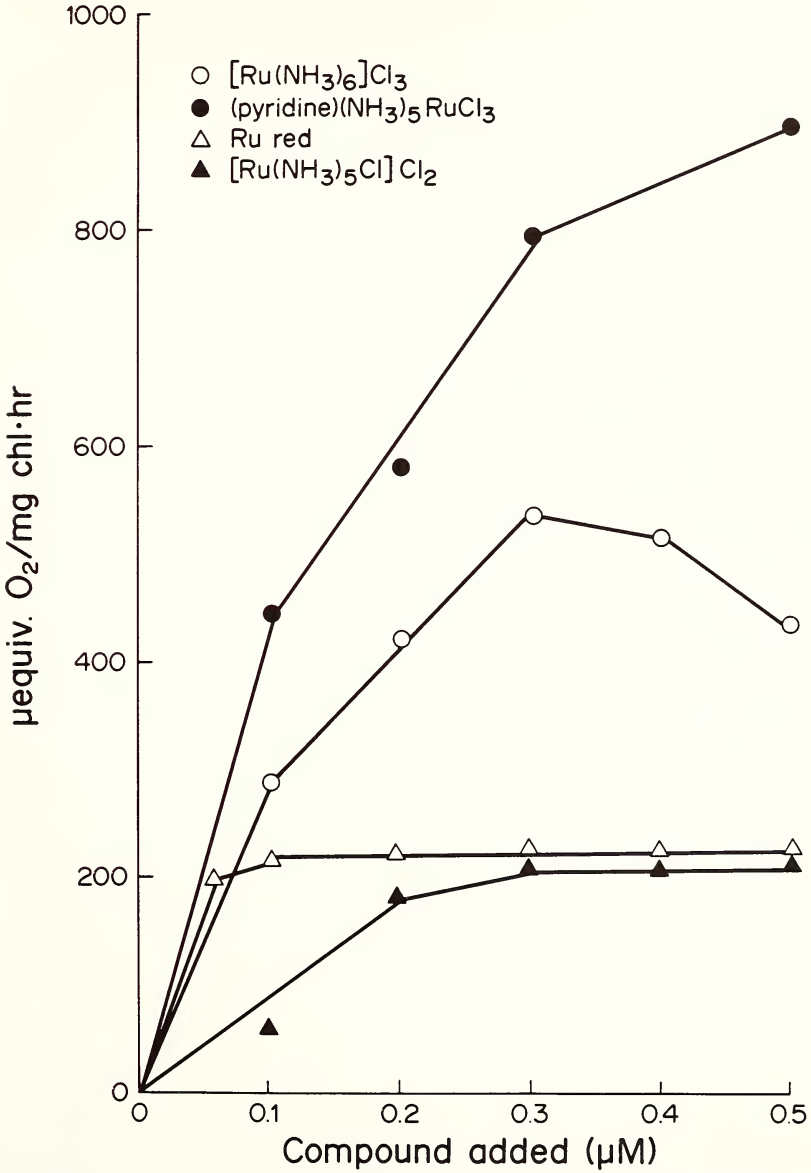

FIGURE 1. *Electron Transport Rates in Spinach Chloroplasts with Ruthenium Ammine Complexes and Ruthenium Red as Electron Acceptors. The reaction mixtures contained chloroplasts (50 μg chlorophyll), 25 mM Tris-Mes buffer, pH 7, 5mM NH_4Cl, 0.5 mM Na azide and ruthenium compounds in concentrations indicated.*

II inhibitors. As Tables I and II show, all reactions tested were inhibited by DCMU, dibromothymoquinone, bathophenanthroline and polylysine, showing that there was no difference between these reactions. This provides evidence that methylviologen and the ruthenium compounds tested act as electron acceptors at the same site or close to each other in PS I.

Since ions can alter local surface charges of membranes, as shown by Barber and associates (2, 12), $MgCl_2$, $CaCl_2$ and bicarbonate ions were tested on the methylviologen and the ruthenium reactions. As Figure 3 shows, Mg^{2+} and Ca^{2+} ions showed very little effect regardless of acceptor used. Bicarbonate, on the other

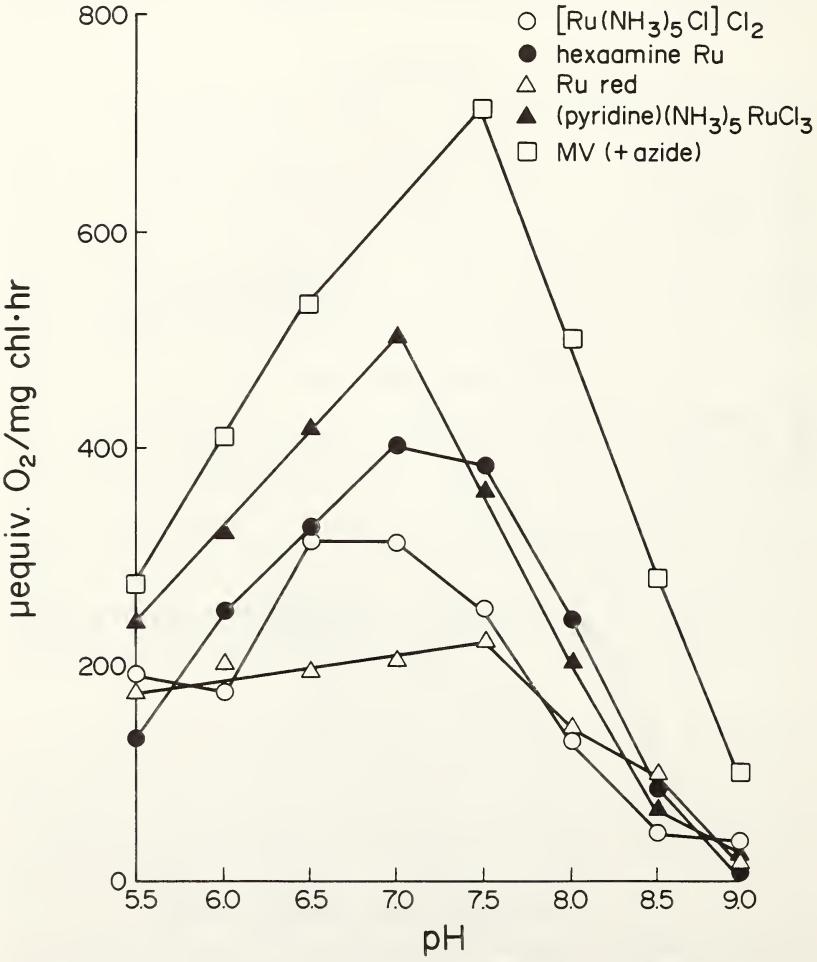

FIGURE 2. *The pH Optima of Electron Transport Reactions with Methylviologen or Ruthenium Compounds as Electron Acceptors. The reaction mixtures were as in Figure 1, except the pH varied as indicated and the optimum concentrations of ruthenium compounds were used.*

TABLE 1. *Inhibition of Ruthenium Electron Transport Pathways in Spinach Chloroplasts*

Inhibitor	Conc.	Electron Transport			
		rate[1]	MV(+ azide) inhibition	$[Ru(NH_3)_6]Cl_3$ rate[1]	inhibition
	(μM)		(%)		(%)
None	—	496	—	463	—
DCMU	5	0	100	51	89
DBMIB	2.5	56	89	113	76
Bathophenanthroline	500	109	78	56	88
Polylysine (35,000 M.W.)	0.2 mg	56	89	113	76

[1] μequiv. 0_2/mg chl · hr

hand, showed less than 25% stimulation of rates with ruthenium compounds as electron acceptors in PS I in contrast to 50% stimulation with methylviologen as the acceptor. This may imply that one of the 2 known bicarbonate sites of action in PS II (4, 14) has been eliminated through the alteration of local membrane surface charges. An alternate explanation of the observed facts may be that there is an attraction between positively-charged ruthenium compounds and negatively-charged bicarbonate ions, but this appears unlikely, since the bicarbonate ions were bound to the chloroplast membrane before the addition of the final electron acceptor. Therefore, the inhibition of ruthenium reduction is chloroplasts by bicarbonate appears to arise from an alteration of local surface charges or through some unknown mechanism. Further studies are in progress to define the mechanism of bicarbonate inhibition on the ruthenium but not on the methylviologen pathway in spinach chloroplasts.

In summary, it was found in this study that ruthenium ammine complexes can be used as artificial electron acceptors in PS I of spinach chloroplasts and that the

TABLE 2. *Inhibition of Ruthenium Electron Transport Pathways in Spinach Chloroplasts*

Inhibitor	*Conc.*	*Electron Transport*			
		(Pyridine) rate[1]	*$(NH_3)_5RuCl_3$ inhibition*	*Ru red rate*[1]	*inhibition*
	μM		%		%
None	—	964	—	186	—
DCMU	5	62	94	0	100
DBMIB	2.5	141	85	0	100
Bathophenanthroline	500	146	85	65	65
Polylysine (35,000 M.W.)	0.2 mg	146	85	45	76

[1] μequiv. 0_2/mg chl · hr

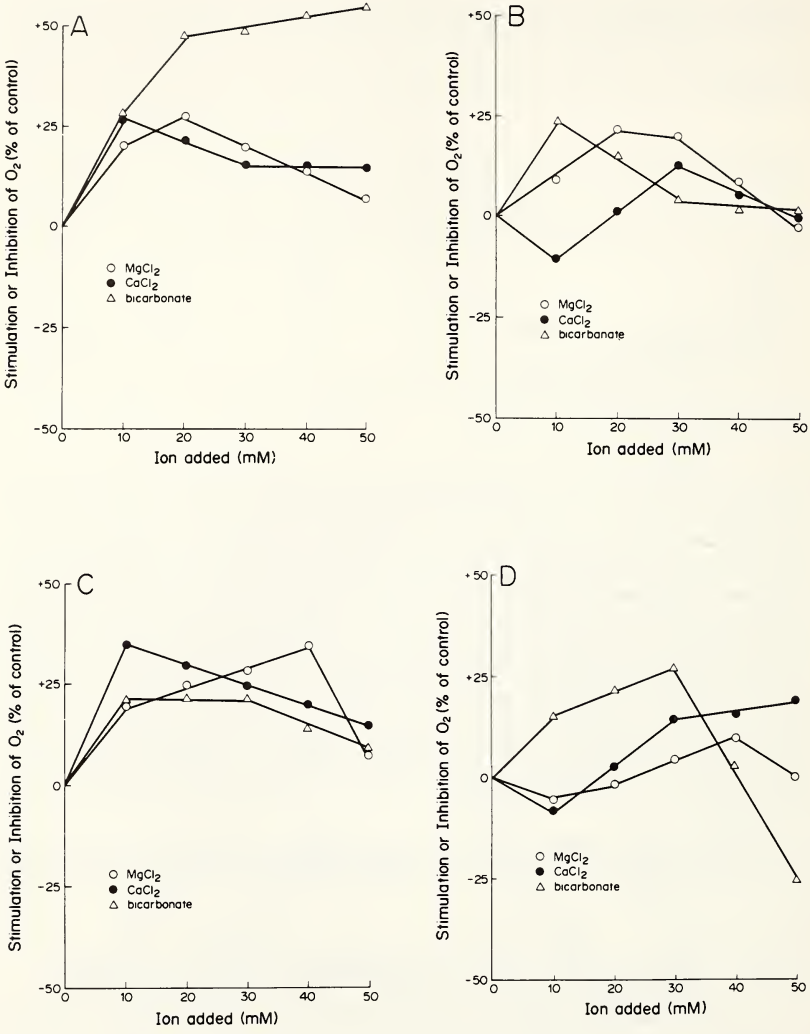

FIGURE 3. *The Effect of Various Ions on the Methylviologen and Ruthenium Compound Electron Transport Pathway in Spinach Chloroplasts. The reaction mixtures contained chloroplasts (50 μg chlorophyll), 25 mM Tris-Mes buffer, pH 7.5 mM NH_4Cl, 0.5 mM Na azide, the optimum concentreation of ruthenium compounds as in Figure 1, and various ions in concentrations indicated.*
A-H_2O → MV(+ azide); B-H_2O → $[Ru(NH_3)_6]$ Cl_3; C-H_2O → $[Ru(NH_3)_5Cl]$ Cl_2; D-H_2O → Ru red.

electron transport pathway with methylviologen as the electron acceptor behaves as the ruthenium pathway toward various inhibitors, except with bicarbonate ions.

Acknowledgments

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A Compilation of Plant Diseases and Disorders in Indiana - 1981

Gail Evans-Ruhl, Richard X. Latin, Paul C. Pecknold, and Donald H. Scott
(computer coordination by Bob Mitchell and Lauren Harmer)

Introduction

The Plant Diagnostic Clinic in the Department of Botany and Plant Pathology at Purdue University is a service of the Cooperative Extension Service, Purdue Agricultural Experiment Station. The clinic provides a free service for accurate identification of weeds, plant diseases, and plant disorders for farmers, commercial growers, homeowners, and other interested persons. Control measures for the diagnosed problems are also offered.

This paper is a compilation of the plant disease and disorder specimens received in the Purdue Plant Diagnostic Clinic from January 1 through October 30, 1981. Such a compilation is an invaluable tool to identify problem areas in which extension personnel need to concentrate. Ultimately, comparisons of yearly disease/disorder compilations will give additional insight to plant disease epidemiological studies in Indiana.

Methods

Plant specimens are received in the Plant Diagnostic Clinic from county extension agents, homeowners, growers, nursery operators, consultants, and others. Specimens are diagnosed visually or by culturing the pathogen on selected media. Once diagnosed, appropriate control measures are suggested for each sample submitted. A computerized log system is utilized to summarize data, to provide an information base for epidemiological studies, and to provide readily accessible reference material on samples submitted. A breakdown of the specimens by crop, handled from January 1 through October 30, 1981 is given in Table 1.

Results

Weather and site related problems were commonplace in Indiana during the 1981 growing season. Intermittent, yet frequent, rainfall throughout the growing season resulted in an increase in foliar and fruit diseases throughout the growing season. Tables 2-8 show the host plant, the disease or disorder diagnosed, the pathogen or cause of disorder, and the number of samples received.

Shade and Ornamental Trees

Disease: Sycamore anthraconse was exceptionally severe throughout Indiana. The disease occurred in all phases, i.e. leaf, twig, stem, and bud blight. Many sycamores were heavily defoliated and developed extensive twig and branch cankers. The disease was most noticeable in late spring (May-June); however, as the season progressed and new growth emerged, anthracnose was less evident. Anthracnose on oak, maple, and ash were common but less severe than sycamore anthracnose (Table 2).

Wet weather, which started at bud break and continued throughout the spring and summer, contributed significantly to the widespread outbreak of anthracnose and many other fungal leaf diseases: examples include scab on crabapple, which caused extensive mid-summer defoliation; *Diplodia* tip blight, which caused lower branch death on many landscape pines; tar spot of maple; and *Botrytis* blight

TABLE 1. *Plant Samples received in the Purdue Plant Diagnostic Clinic Jan. 1 through Oct. 30, 1981.*

Plant Specimen	Number of Samples	Disease[1]	Disorder[2]	Chemical[3]	Nutritional[4]
AGRONOMIC (19%)					
Corn	118	55	32	13	9
Soybeans	67	36	18	6	6
Small Grain	77	59	10	4	4
Forage Grasses and Legumes	52	37	24	2	9
ORNAMENTAL (36%)					
Trees-Shade and Ornamental	406	149	201	7	9
Shrubs and Groundcover	100	36	52	7	1
Flowers	47	29	11	2	2
House plants	41	11	17	1	3
FRUIT (11%)					
Tree Fruit	108	55	42	4	0
Small Fruit	62	37	18	5	0
VEGETABLE (12%)	193	80	50	32	14
TURFGRASS (3%)	50	26	27	0	0
PLANT IDENTIFICATION '12%)	199	–	–	–	–
FORWARDED TO ENTOMOLOGY (7%)	115	–	–	–	–
Total	1635	610	502	83	57

[1]Problem caused by an infectious disease causing agent, e.g. fungus, bacterium, virus, mycoplasma, nematode.
[2]Problem caused by noninfectious environmental stress, e.g. wind, drought, heat, soil compaction.
[3]Problem caused by herbicide/pesticide misuse.
[4]Problem caused by fertilizer misuse.

TABLE 2. *Shade and Ornamental Trees—Diseases and Disorders*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Abies (FIR)		
Miscellaneous Disorders		
Needle Tip Burn	Stress factor(s)	4
Needle Yellowing/Drop	Normal needle drop	1
Acer (MAPLE)		
Anthracnose	*Gloeosporium apocryptum*	10
Leaf Spot	*Phyllosticta* sp.	1
Canker	*Nectria* sp.	1
Tar Spot	*Rhytisma acerinum*	1
Canker	*Strumella* sp.	1
Powdery Mildew	*Uncinula circinata*	1
Miscellaneous Disorders		
Scorch	Stress factor(s)	25
Leaf Spot	Physiological	3
Decline	Stress factor(s)	23
Herbicide Injury	Spray drift	4
Sooty Mold	Insect honeydew secretions	3
Dieback	Transplant shock	1
Canker	Hail	1
Leaf mottle	Genetic	1

TABLE 2. — Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Betula (BIRCH)		
Leaf Spot	*Phyllosticta betulina*	1
Miscellaneous Disorders		
Scorch	Heat, wind, and drought	2
Chlorosis	Stress factor(s)	2
Leaf Spot	Nutrient imbalance	1
Carya (HICKORY)		
Downy Spot	*Microstroma juglandis*	4
Anthracnose	*Gnomonia caryae*	1
Leaf Spot	*Phyllosticta caryae*	1
Miscellaneous Disorder		
Canker	Stress factor(s)	1
Carya illinoensis (PECAN)		
Miscellaneous Disorder		
Poor Seed Development	Improper pollination	1
Castanea (CHESTNUT)		
Wood Rotter	*Polyporus cinnabarinis*	1
Catalpa (CATALPA)		
Miscellaneous Disorder		
Leaf Scorch	Stress factor(s)	1
Cercis (RED BUD)		
Canker	*Botryosphaeria* sp.	1
Miscellaneous Disorders		
Leaf Scorch	Heat, wind, drought	4
Bark Shedding	Natural	1
Leaf Spot	Stress factor(s)	2
Sooty mold	Insect honeydew secretions	1
Cornus (DOGWOOD)		
Canker	*Botryosphaeria* sp.	2
Miscellaneous Disorders		
Winter damage	Desiccation	1
Chlorosis	Stress factor(s)	2
Leaf Scorch	Heat, wind, drought	2
Crataegus (HAWTHORN)		
Leaf Spot	*Fabraea maculata*	1
Cedar-Hawthorn Rust	*Gymnosporangium globosum*	1
Elaeagnus (RUSSIAN OLIVE)		
Canker	*Fusicoccum elaeagni*	2
Fagus (BEECH)		
Miscellaneous Disorders		
Dieback	Stress factor(s)	1
Decline	Stress factor(s)	1
Fraxinus (ASH)		
Anthracnose	*Gloeosporium aridum*	8
Rust	*Puccinia sparganoides*	1
Miscellaneous Disorders		
Leaf Drop	Stress factor(s)	1
Leaf Scorch	Heat, wind, drought	1
Ginkgo (GINKGO)		
Miscellaneous Disorder		
Scorch	Heat, wind, drought	1
Gleditsia (HONEY LOCUST)		
Fireblight	*Erwinia amylovora*	1
Miscellaneous Disorder		
Scorch	Improper root establishment	1

TABLE 2.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Juniperus virginiana (RED CEDAR)		
Twig Blight	*Phomopsis juniperovora*	2
Cedar-apple Rust	*Gymnosporangium juniperi-virginianae*	1
Larix (LARCH)		
Miscellaneous Disorder		
Scorch	Improper root establishment	1
Liquidambar (SWEET GUM)		
Leaf Spot	*Cladosporium* sp.	1
Miscellaneous Disorder		
Scorch	Stress factor(s)	3
Liriodendron (TULIP TREE)		
Powdery Mildew	*Erysiphe polygoni*	1
Miscellaneous Disorders		
Leaf Yellowing/Spotting	Natural stress	7
Scorch	Heat, wind, drought	1
Herbicide injury	Spray drift	1
Sooty mold	Insect honeydew secretions	1
Decline	Stress factor(s)	1
Magnolia (MAGNOLIA)		
Leaf Spot	*Phyllosticta* sp.	1
Miscellaneous Disorders		
Dieback	Stress factor(s)	1
Scorch	Heat, wind	1
Malus (CRABAPPLE)		
Scab	*Venturia inaequalis*	4
Canker	*Botryosphaeria* sp.	1
Cedar-Apple Rust	*Gymnosporangium juniperi-virginianae*	1
Miscellaneous Disorder		
Scorch	Stress factor(s)	1
Morus (MULBERRY)		
Leaf Spot	*Mycosphaerella mori*	1
Miscellaneous Disorder		
Scorch/Leaf Drop	Stress factor(s)	1
Picea (SPRUCE)		
Canker	*Cytospora kunzei*	6
Needlecast	*Rhizosphaera kalkoffii*	2
Miscellaneous Disorders		
Dieback	Stress factor(s)	18
No growth	Transplant shock	1
Needle Tip Burn	Poor root establishment	3
Chlorosis	Stress factor(s)	2
Pinus (PINE)		
Tip Blight	*Diplodia pinea*	27
Needle Blight	*Dothistroma pini*	2
Needle Cast	*Lophodermium pinastri*	2
Pinewood Nematode	*Bursaphelenchus lignicolus*	3
Miscellaneous Disorders		
Decline	Poor drainage, site-stress	27
Winter damage	Desiccation	7
Dieback	Poor root establishment	4
Needle Tip Burn	Heat, wind, drought	7
Chlorosis	Stress factor(s)	5
Mechanical damage	Unidentified	1
Sap	Normal	1
Yellowing/Needle drop (previous years growth)	Natural	4

TABLE 2.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Platanus (SYCMORE)		
Anthracnose	*Gnomonia veneta*	2
Powdery Mildew	*Oidium obductum*	1
Populus (POPULAR)		
Canker	*Cytospora* sp.	4
Rust	*Melampsora* sp.	1
Miscellaneous Disorders		
Leaf Drop	Flood shock	1
Scorch	Stress factor(s)	1
Prunus (PURPLE LEAF PLUM)		
Leaf Spot	Unidentified fungus	1
Miscellaneous Disorder		
Winter damage	Desiccation	1
Prunus (ORIENTAL CHERRY)		
Miscellaneous Disorder		
Scorch	Stress factor(s)	1
Quercus (OAK)		
Anthracnose	*Gnomonia quercina*	7
Leaf Blister	*Taphrina coerulescens*	4
Leaf Spot	*Actinopelte dryina*	21
Hedgehog fungus	*Hydnum erinaceus*	1
Powdery Mildew	*Phyllactinia corylea*	2
Powdery Mildew	*Microsphaera alni*	2
Miscellaneous Disorders		
Chlorosis	Iron deficiency	10
Decline (Dieback)	Stress factor(s)	2
Scorch	Wind, heat, and stress	7
Bark Proturberances	Unknown	1
Split bark	Lightning	1
Early leaf drop	Stress	1
Heart discoloration	Unidentified bacteria	1
Salix (WILLOW)		
Crown Gall	*Agrobacterium tumefaciens*	1
Canker	*Nectria* sp.	1
Canker	*Cytospora chrysosperma*	1
Canker	*Botrydiplodia* sp.	1
Miscellaneous Disorder		
Dieback	Stress factor(s)	1
Sorbus (MOUNTAIN ASH)		
Canker Complex	Sunscald/unidentified fungus	4
Leaf Spot	*Phyllosticta* sp.	3
Scab	*Venturia inaequalis*	1
Miscellaneous Disorders		
Scorch	Heat, wind, drought	7
Herbicide injury	Unidentified chemical	1
Tsuga (HEMLOCK)		
Miscellaneous Disorder		
Dieback	Improper root establishment	1
Ulmus (ELM)		
Dutch Elm Disease	*Ceratocystis ulmi*	2
Miscellaneous Disorders		
Scorch	Stress factor(s)	3
Wilt	Stress factor(s)	2

(grey mold), a frequent problem on a number of ornamentals. Late season infections of sycamore and other trees by powdery mildew and of oak by *Actinopelte* leaf spot were also common.

Pine wilt nematode, a disease first reported in 1980 (2), was identified on samples of pine from 23 counties; however, no widespread outbreak of this potentially serious disease was reported.

Disorders: Leaf scorch and tree decline were the most common disorders of shade and ornamental trees, especially maple, mountain ash, and oak. However, these disorders were less severe than in previous years due to adequate rainfall in most areas of Indiana. Herbicide injury was also noted on several tree species, especially redbud. During early fall many pines yellowed extensively and dropped older, inner needles. This late season needle drop is natural on most pines, but caused concern due to the simultaneous, widespread yellowing.

Ornamentals

Diseases: Although juniper tip blight was prevalent from early to mid-spring, only the early season growth was damaged. Other commonly diagnosed shrub diseases included honeysuckle leaf blight and crown gall on euonymous (Table 3). Powdery

TABLE 3.—*Diseases and Disorders*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Althaea (HOLLYHOCK)		
Rust	*Puccinia malvacearum*	1
Miscellaneous Disorder		
Leaf Spot	Environmental stress factor(s)	1
Antirrhinum (SNAPDRAGON)		
Root Rot	*Rhizoctonia solani*	1
Aralia (MING ARALIA)		
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Araucaria (NORFOLK ISLAND PINE)		
Root Rot	*Pythium* spp.	1
Berberis (BARBERRY)		
Miscellaneous Disorder		
Leaf Spot	Environmental stress factor(s)	1
Boxus (BOXWOOD)		
Miscellaneous Disorder		
Dieback	Stress factor(s)	1
Chrysalidocarpus (ARECA PALM)		
Root Rot	*Rhizoctonia solani*	1
Miscellaneous Disorder		
Leaf Scorch	Improper cultural care	1
Chrysanthemum (CHRYSANTHEMUM)		
Stem/Root Rot	*Rhizoctonia solani*	1
Root Rot	*Pythium* spp.	1
Stem Rot	*Fusarium solani*	1
Wilt	*Fusarium oxysporum*	3
Leaf Spot	*Alternaria* sp.	1
Bactrial Leaf Spot	*Pseudomonas cichorii*	2
Cissus (GRAPE IVY)		
Leaf Blight	*Botrytis cinerea*	1

TABLE 3.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Citrus (LEMON TREE)		
Leaf Spot	*Mycosphaerella* sp.	1
Anthracnose	*Glomerella cingulata*	1
Clematis (CLEMATIS)		
Chlorosis	Soil pH imbalance	1
Cornus (DOGWOOD)		
Miscellaneous Disorder		
Enlarged Lenticels	Stress factor(s)	1
Cotoneaster (COTONEASTER)		
Canker	*Phytophthora* sp.	1
Crassula (JADE PLANT)		
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Crataegus (HAWTHORN)		
Leaf Blight	*Fabraea thuemenii*	1
Fire Blight	*Erwinia amylovora*	1
Miscellaneous Disorder		
Dieback	Winter desiccation	2
Cydonia (QUINCE)		
Miscellaneous Disorder		
Scorch	Environmental stress	2
Dianthus (CARNATION)		
Miscellaneous Disorder		
Root Rot	Fertilizer burn	1
Dieffenbachia (DIEFFENBACHIA)		
Leaf Rot	*Erwinia dieffenbachia*	1
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Dracaena (SNAKE PLANT)		
Miscellaneous Disorder		
Leaf Spot	Flouride Toxicity	1
Euonymous (WINGED EUONYMOUS)		
Crown Gall	*Agrobacterium tumefaciens*	2
Miscellaneous Disorders		
Chlorosis	Improper root establishment	1
Leaf Distortion	Herbicide misuse	1
Exacum (EXACUM)		
Stem Canker	*Botrytis cinerea*	2
Ficus (WEEPING FIG)		
Root/Stem Rot	*Pythium* spp.	1
Miscellaneous Disorders		
Leaf Scorch	Improper cultural care	3
Bark Shedding	Improper cultural care	1
Filices (FERN)		
Miscellaneous Disorders		
Scorch	Improper site location	1
Scorch	Improper heater ventillation	1
Forsythia (FORSYTHIA)		
Miscellaneous Disorder		
Leaf Discoloration	Environmental stress	1
Geranium (GERANIUM)		
Root Rot	*Pythium* spp.	1
Miscellaneous Disorder		
Chlorosis	Soil pH imbalance	1

TABLE 3.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Hedera (ENGLISH IVY)		
Miscellaneous Disorder		
Dieback	Winter desiccation	1
Hemerocallis (DAYLILLY)		
Leaf Spot	*Cercospora hemerocallis*	1
Ilex (HOLLY)		
Miscellaneous Disorders		
Leaf Scorch	Winter injury	2
Leaf Blotch	Nonparasitic	1
Impatiens (IMPATIEN)		
Root Rot	*Rhizoctonia solani*	1
Iris (IRIS)		
Leaf Blotch	*Didymellina macrospora*	2
Soft Rot	*Erwinia carotovora*	1
Bulb Blight	*Fusarium* spp.	1
Juniperus (JUNIPER)		
Twig Blight	*Phomopsis juniperovora*	4
Tip Blight	*Diplodia* sp.	1
Miscellaneous Disorders		
Leaf Scorch	Herbicide misuse	1
Dieback	Site/stress	1
Lathyrus (SWEET PEA)		
Miscellaneous Disorder		
Leaf Scorch	Environmental stress factor(s)	1
Ligustrum (PRIVET)		
Stem/Root Rot	*Rhizoctonia solani*	1
Powdery Mildew	*Microsphaera alni*	1
Miscellaneous Disorders		
Dieback	Stress factor(s)	3
Leaf Discoloration	Clay site/root restriction	1
Lilium (LILY)		
Root Rot	*Pythium* spp.	1
Lonicera (HONEYSUCKLE)		
Leaf Blight	*Herpobasidium deformans*	2
Magnolia (MAGNOLIA)		
Miscellaneous Disorders		
Dieback	Cold injury	1
Chlorosis	Nutrient imbalance	1
Orchid (ORCHID)		
Cymbidium Mosaic	Cymbidium Mosaic Virus	1
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Pachysandra (JAPANESE SPURGE)		
Root Rot	*Rhizoctonia solani*	1
Paeonia (PEONY)		
Anthracnose	*Gloeosporium* sp.	1
Leaf Spot	*Alternaria* sp.	1
Leaf Blotch	*Cladosposium paeoniae*	1
Parthenocissus (BOSTON IVY)		
Leaf Spot	*Guignardia bidwelli*	1
Peperomia (PEPEROMIA)		
Miscellaneous Disorder		
Chlorosis	Improper fertilization	1

TABLE 3.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Petunia (PETUNIA)		
Root Rot	*Rhizoctonia solani*	2
Philadelphus (MOCK ORANGE)		
Miscellaneous Disorders		
Leaf Spot	Spray damage	1
Leaf Spot	Environmental stress	1
Philodendron (PHILODENDRON)		
Miscellaneous Disorder		
Leaf Spot	Improper cultural practices	1
Phlox (PHLOX)		
Powdery Mildew	*Erysiphe cichoracearum*	1
Physocarpus (NINEBARK)		
Powdery Mildew	*Sphaerotheca macularis*	1
Prunus (PLUM)		
Miscellaneous Disorders		
Dieback	Winter desiccation	1
Scorch	Improper root establishment	1
Pyracantha (FIRETHORN)		
Scab	*Fusicladium pyracanthae*	2
Rhamnus (BUCKTHORN)		
Miscellaneous Disorder		
Leaf Spot	Herbicide misuse	1
Rhododendron (AZALEA)		
Miscellaneous Disorder		
Leaf Scorch	Environmental stress	2
Rhododendron (RHODODENDRON)		
Twig Canker	*Phytophthora* sp.	1
Leaf Spot	*Pestalotia macrotricha*	1
Miscellaneous Disorders		
Leaf Scorch	Stress factor(s)	3
Stunted Flowers	Cultural	1
Rosa (ROSE)		
Rose Yellow Mosaic	Virus	2
Stem Canker	Unidentified	2
Black Spot	*Diplocarpon rosae*	2
Miscellaneous Disorders		
Scorch	Stress factor(s)	3
Herbicide Damage	Improper use	3
Chlorosis	Nutrient imbalance	1
Dieback	Stress factor(s)	3
Sansevieria (BIRD'S NEST SANSEVIERIA)		
Miscellaneous Disorder		
Root Rot	Improper cultural care	1
Schefflera (SCHEFFLERA)		
Miscellaneous Disorder		
Leaf Spot	Nutrient imbalance	1
Schlumbergera (CHRISTMAS CACTUS)		
Miscellaneous Disorder		
Dieback	Improper cultural care	1
Scindapsus (POTHOS)		
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Solanum (JERUSALEM CHERRY)		
Stem Canker	*Rhizoctonia solani*	1

TABLE 3.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Spathiphyllum (SPATHIPHYLLUM)		
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Syringa (LILAC)		
Powdery mildew	*Microsphaera alni*	2
Bacterial Blight	*Pseudomonas syringae*	1
Miscellaneous Disorders		
Dieback	Environmental stress	1
Leaf Scorch	Stress factor(s)	2
Stem Canker	Mechanical	1
Tagetes (MARIGOLD)		
Root Rot	*Rhizoctonia solani*	
Taxus (YEW)		
Yew Dieback	Poor site location/root rot complex	7
Miscellaneous Disorder		
Herbicide Injury	Spray drift	2
Thuja (ARBORVITAE)		
Canker	Unidentified	1
Twig Blight	*Pestalotia funerea*	2
Miscellaneous Disorders		
Inner branch browing	Natural needle death	2
Scorch	Environmental stress	2
Tulip (TULIP)		
Tulip Fine	*Botrytis tulipae*	1
Vaccinium (CRANBERRY)		
Wilt	Environmental stress factors	1
Viburnum (VIBURNUM)		
DEcline	Unidentified root rotter	1
Vinca (PERIWINKLE)		
Crown Canker	*Rhizoctonia solani*	3
Canker/Dieback	*Phoma exigua* var. *exigua*	1
Viola (VIOLET)		
Rust	*Puccinia violae*	1

mildew was severe during early fall on lilacs and annual flowers. *Fusarium* wilt of chrysanthemums occurred in a number of commercial greenhouses, apparently originating from stock plant sources. Rose diseases were frequent and varied; black spot, powdery mildew, canker, and virus diseases were the most common problems.

Disorders: Scorch and natural browning of inner foliage were common disorders of arborvitae. Numerous site-related and other cultural problems were recorded for rhododendrons. Herbicide injury was most common on euonymous. As in previous years (1, 2, 3), houseplant problems were primarily related to poor cultural conditions, e.g. overwatering, salt build-up, low humidity, etc.

Tree Fruits

Diseases: Excessive rainfall throughout the growing season resulted in a number of fungal leaf spot and fruit rot diseases (Table 4). Apple scab caused widespread injury in both commercial apple orchards and home plantings. Sooty blotch and

flyspeck were prevalent on fruit at harvest on most apple cultivars. The blossom blight phase of fire blight was sporadic but severe in a number of commercial apple orchards. Brown rot on peach, nectarine, and cherry was the most common and damaging early season disease of stone fruits.

TABLE 4. *Fruit Trees—Diseases and Disorders.*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Diospyros (PERSIMMON)		
Miscellaneous Disorder		
Decline	Stress factor(s)	1
Malus sylvestris (APPLE)		
Powdery Mildew	*Podosphaera oxyacanthae*	1
Crown Rot	*Phytophthora cactorum*	1
Stunting	Nematodes	2
Fireblight	*Erwinia amylovora*	3
Leaf Spot	*Fabraea maculata*	1
Leave Spot	*Phyllosticta* spp.	1
Frogeye Leaf Spot	*Physalospora obtusa*	5
Scab	*Venturia inaequalis*	8
Miscellaneous Disorders		
Scorch	Wind and drought	9
Herbicide Injury	Spray drift	2
Dieback	Stress factor(s)	2
Chemical Injury	Improper use	1
Measles	Boron deficiency	1
Prunvs americana (PLUM)		
Black Knot	*Dibotryon morbosum*	3
Brown Rot	*Monilinia fructicola*	1
Miscellaneous Disorders		
Cold Injury	Low temperature	1
Chemical Injury	Improper use	1
Prunus armeniaca (APRICOT)		
Dieback		
Scorch	Stress factor(s)	2
Slash Rotter	Unidentified fungus	1
Prunus avium (CHERRY)		
Cherry Leaf Spot	*Coccomyces hiemalis*	6
Brown Rot	*Monilinia fructicola*	3
Powdery Mildew	*Podosphaera oxyacanthae*	2
Bacterial Leaf Spot	*Xanthomonas pruni*	1
Miscellaneous Disorders		
Dieback	Stress factor(s)	6
Scorch	Wind, heat, and drought	2
Cold Injury	Low temperature	2
Prunus persica (PEACH)		
Bacterial Spot	*Xanthomonas pruni*	6
Scab	*Cladosporium carpophilum*	3
Leaf Curl	*Taphrina deformans*	3
Brown Rot	*Monilina fructicola*	3
Miscellaneous Disorders		
Fruit Rot	Stress factor(s)	2
Scorch	Wind, heat and drought	3
Dieback	Stress factor(s)	1
Prunus persica var. *nectarine* (NECTARINE)		
Bacterial Leaf Spot	*Xanthomonas pruni*	2
Brown Rot	*Monilina fructicola*	2
Miscellaneous Disorders		
Fruit split	Excess water	1

TABLE 4. — Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Pyrus communis (PEAR)		
Fire Bight	*Erwinia amylovora*	2
Canker	*Cytospora* spp.	1
Scab	*Venturia pyrina*	1
Miscellaneous Disorders		
Scorch	Wind, drought, and heat	9
Chemical Injury	Improper use	1
Dieback	Stress factor(s)	1
Fruit crack	Excess water	1
Sooty mold	Insect honeydew secretions	1

Disorders: Leaf scorch and decline were the most commonly recorded disorders (Table 4). A late spring frost in southeastern Indiana resulted in extensive frost ring injury on apples.

Small Fruits

Diseases: The most common disease of small fruits was black root rot of strawberry (Table 5). The cause of this disease is unknown, however, it is likely a complex interaction between environmental (cold injury plus heavy, wet soils) factors and certain soil borne fungi (*Pythium, Rhizoctonia*). The disease is more common in older strawberry plantings on heavy, poorly drained soil. Anthracnose was the most frequently recorded disease of brambles, especially raspberry. Various stem canker diseases occurred on blueberry, and black rot and downy mildew were the most common grape diseases. Downy mildew of grape was severe in both northern and southern counties due to the cool, wet spring conditions.

Disorders: Environmental and site related problems were the major disorders recorded for small fruits. Herbicide injury was common on grape.

Turfgrass

Diseases: As in previous years (1,2), *Helminthosporium* leaf spot and melting out caused by *Helminthosporium* spp. were the most widespread diseases of Kentucky bluegrass (Table 6). *Helminthosporium* melting out coupled with excessive thatch and environmental stress were responsible for killing areas of turf in many lawns. The unidentified problem reported last year (2) on Toronto C-15 bentgrass occurred on at least two Indiana golf courses this season. Cool weather brown patch caused by *Rhizoctonia* was observed in early spring. Red thread was also reported in Marion county.

Disorders: Improper cultural care and improper knitting of sod were common noninfectious problems.

Vegetables

Diseases: Weather conditions unfavorable for seedling maturation promoted an unusually high incidence of damping off disease of melon seedlings (Table 7). Most melon growers in southwestern Indiana observed damping off of watermelon and cantaloupe seedlings grown in cold frames for later transplanting to the field. Isolates of *Pythium* spp. were readily obtained from infected melon seedlings.

TABLE 5. *Small Fruits—Diseases and Disorders*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Fragaria grandiflora		
Black Root Rot	Specific pathogen(s) unknown site stress	8
Leaf Scorch	*Diplocarpon earliana*	2
Root Rot	*Fusarium* spp./*Rhizoctonia* app.	2
Leaf Blight	*Dendrophoma obscurans*	1
Common Leaf Spot	*Mycosphaerella fragariae*	1
Miscellaneous Disorders		
Slime Mold	*Physarum cinereum*	2
Chlorosis	Stress factor(s)	1
Malformed Fruit	Unidentitied	1
Root Rot	Poor site	1
Ribes sativum (CURRANT)		
Miscellaneous Disorder		
Dieback	Stress factor(s)	1
Rubus (RASPBERRY)		
Spur Blight	*Didymella applanata*	1
Anthracnose	*Elsinoe veneta*	1
Rust	*Gymnoconia peckiana*	1
Leaf Spot	*Septoria* spp.	1
Leaf Crinkle	Virus	1
Crumbly Berry	Virus	1
Miscellaneous Disorders		
Dieback	Stress factor(s)	6
Scorch	Heat, wind, and drought	2
Rubus (DEWBERRY)		
Rust	*Kunkelia nitens*	1
Vaccinium (BLUEBERRY)		
Twig Canker	*Phomospsis vaccinii*	1
Miscellaneous Disorder		
Dieback	Stress factor(s)	1
Vitis (GRAPE)		
Black Rot	*Guignardia bidwelli*	3
Downy Mildew	*Plasmopora viticola*	2
Miscellaneous Disorders		
Dieback	Stress factor(s)	2
Cold Injury	Low temperatures	1
Herbicide Injury	Spray drift	4

Watermelon seedlings appeared to be more severely affected than muskmelons. Some growers did not produce watermelons in 1981 because of widespread losses from damping off of seedlings and many others had greatly reduced acreages.

Cucurbit downy mildew occurred on muskmelon vines to a moderate degree throughout the state. Epidemic development was limited by the few consecutive days of disease favorable weather. Toward the later part of the season, powdery mildew was rampant among all cucurbits. Late season muskmelons and pumpkins sustained the most damage from powdery mildew. Bacterial wilt of muskmelon was observed in trace amounts except in fields where growers did not exercise proper vector control.

One of the major diseases affecting tomato production in Indiana was bacterial canker, caused by *Corynebacterium michiganense*. Both fresh market and process-

TABLE 6. *Turf—Diseases and Disorders.*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Poa pratensis (BLUEGRASS)		
Leaf Spot	*Helminthosporium* spp.	20
Fusarium Blight	*Fusarium roseum* complex	2
Brown Patch	*Rhizoctonia solani*	2
Dollar Spot	*Sclerotinia homeocarpa*	1
Stripe Smut	*Ustilago striiformis*	1
Slime Mold	*Physarum cinereum*	1
Cottony Blight	*Pythium aphanidermatum*	1
Anthracnose	*Colletotrichum graminicola*	1
Red Thread	*Corticium fuciforme*	2
Rust	*Puccinia* sp.	1
Miscellaneous Disorders		
Excessive Thatch	Improper cultural care	19
Scorch	Stress factor(s)	11
Dieback	Improper knitting of sod	2
Chemical Injury	Improper use	1

TABLE 7. *Vegetables—Diseases and Disorders*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Allium cepa (ONION)		
Botrytis Neck Rot	*Botrytis allii*	1
Asparagus officinalis (ASPARAGUS)		
Twig Dieback	*Alternaria* spp.	1
Beta vulgaris var. *cicla* (SWISS CHARD)		
Miscellaneous Disorder		
Canker	Environmental/mechanical	1
Brassica oleracea var. *botrytis* (CAULIFLOWER)		
Downy Mildew	*Peronospora parasitica*	1
Wirestem	*Rhizoctonia solani*	1
Leaf Spot	Unidentified bacterium	1
Brassica oleracea var. *capitata* (CABBAGE)		
Cabbage Yellows	Fusarium spp.	1
Wirestem	*Rhizoctonia solani*	1
Miscellaneous Disorders		
Interveinal Chlorosis	Environmental	1
Herbicide Injury	Spray drift	1
Wilt	Desiccation	1
Brassica rapa (TURNIP)		
Leaf Spot	*Cercosporella brassicae*	1
Miscellaneous Disorder		
Elongated tuber	Unidentified	1
Brasica ruvo (BROCCOLI)		
Leaf Spot	Unidentified bacterium	1
Capsicum frutescens (PEPPER)		
Bacterial Spot	*Xanthomonas vesicatoria*	1
Stem Canker	*Rhizoctonia solani*	1
Root Rot	*Pythium* spp.	1

TABLE 7.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Miscellaneous Disorders		
Leaf Scorch	Stress factor(s)	2
Edema	Environmental stress	1
Fruit Injury	Sunscald	2
Leaf Scorch	Nutritional imbalance	1
Herbicide Injury	Spray drift	1
Shrunken Fruit	Unidentified	1
Citrullus vulgaris (WATERMELON)		
Seedling Damping Off	*Pythium* spp.	1
Blossom Rot	*Pythium* spp.	1
Miscellaneous Disorders		
Leafspot	Fertilizer burn	1
Scorch	Stress factor(s)	1
Herbicide Injury	Atrazine carryover	1
Cucumis melo (CANTALOUPE)		
Downy Mildew	*Pseudoperonospora cubensis*	2
Damping off	*Pythium* spp.	1
Wilt	*Fusarium* spp.	3
Bacterial Wilt	*Erwinia tracheiphila*	1
Miscellaneous Disorders		
Scorch	Stress factor(s)	5
Scorch	Copper burn	4
Herbicide Injury	Atrazine carryover	1
Cucumis sativus (CUCUMBER)		
Bacterial Wilt	*Erwinia tracheiphila*	1
Powdery Mildew	*Erysiphe cichoracearum*	1
Leaf Blight	*Alternaria cucumerina*	1
Damping Off	*Pythium* spp.	1
Miscellaneous Disorder		
Leaf Scorch	Environmental stress	1
Cucurbita moschata (PUMPKIN)		
Powdery Mildew	*Erysiphe cichoracearum*	1
Cucurbita pepo (ZUCCHINI)		
Miscellaneous Disorder		
Herbicide Injury	Spray drift	1
Ipomoea batatas (SWEET POTATO)		
Scurf	*Monilochaetes infuscans*	2
Tuber Rot	*Fusarium* sp.	1
Miscellaneous Disorder		
Tuber Discoloration	Environmental stress	1
Lycopersicon esculentum (TOMATO)		
Gray Mold Leafspot (Hydroponics)	*Botrytis* sp.	5
Black Dot Root Rot	*Colletotrichum coccodes*	1
Double Streak Virus	TMV + PVX Virus	2
Tobacco Mosaic Virus	Tobacco Mosaic Virus	2
Damping Off	*Pythium* sp.	1
Stem Canker	*Rhizoctonia solani*	1
Septoria Leafspot	*Septoria lycopersici*	8
Bacterial Speck	*Pseudomonas syringae* (tomato)	3
Bacterial Wilt	*Pseudomonas solanacearum*	3
Bacterial Spot	*Xanthomonas vesicatoria*	2
Bacterial Canker	*Corynebacterium michiganense*	5
Stem Rot (Hydroponics)	*Erwinia* sp.	1
Root Knot Nematode	*Meloidogyne incognita*	1
Root Knot Nematode	*Meloidogyne hapla*	1

TABLE 7.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Miscellaneous Disorders		
Leaf Yellowing/Curling (Hydronponics)	Nutrient imbalance	6
Chemical Injury (Hydroponics)	Heater fumes	1
Dieback	Environmental stress	3
Corky Root	Salt build-up	2
Leaf Burn	Excess fertilizer	6
Herbicide Injury	Improper use	11
Walnut Wilt	Walnut toxin	2
Stunting	Nutrient deficiency	1
Leaf Scorch	Environmental stress	1
Leaf Roll	Physiological	1
Stem Bruise	Mechanical	1
Improper Stylar Closing	Genetic	1
Wilt	Lightning	1
Blotchy Ripening	Environmental stress	1
Fruit Crack	Excess water	1
Panax (GINSENG)		
Root Rot	*Rhizoctonia solani*	1
Leafspot	*Septoria* sp.	1
Phaseolus vulgaris (SNAP BEANS)		
Root Rot	*Rhizoctonia solani*	1
Stem Rot	*Sclerotinia sclerotiorum*	2
Common Bean Mosaic	Common Bean Mosaic Virus	2
Common Rust	*Uromyces phaseoli* var. *typica*	1
Miscellaneous Disorders		
Chemical Injury	Spray drift	5
Cupping of Leaves	Excess water	1
Stunted	Stress factor(s)	1
Pod Discoloration	Genetic/environmental	2
Pisum (PEA)		
Herbicide Injury	Spray drift	2
Rheum (RHUBARB)		
Leaf Spot	*Ascochyta rhei*	2
Root/Crown Rot	*Phytophthora* sp.	1
Solanum melongena (EGGPLANT)		
Miscellaneous Disorder		
Leafspot	Nutritional imbalance	
Solanum tuberosum (POTATO)		
Common Scab	*Streptomyces scabies*	4
Blackleg	*Erwinia atroseptica*	4
Root/Stem Rot	*Rhizoctonia solani*	1
Black Dot Root Rot	*Colletotrichum coccodes*	1
Miscellaneous Disorders		
Stem Canker	Herbicide injury	1
Enlarged Lenticels	Excess water	4
Tuber Necrosis	Cold injury	3
Leaf Scorch	Nutritional imbalance	1
Herbicide Injury	Spray drift	1
Tragopogon (SALSIFY)		
Root Knot Nematode	*Meloidogyne* sp.	1
Zea mays var. *saccharata* (SWEET CORN)		
Miscellaneous Disorders		
Leaf Discoloration	Nutritional imbalance	1
Leaf Spot	Paraquat	1
Leaf Blotch	Environmental	1

ing varieties were damaged by canker. In many cases the source of the inoculum was traced to shipments of transplants from southern states. However, several tomato producers with Indiana grown transplants also suffered losses from bacterial canker. Bacterial spot and speck on tomato were sporadic in Indiana fields this year. Plants infected with the southern blight fungus (*Sclerotium rolfsii*) and with the bacterial wilt pathogen (*Pseudomonas solanacearum*) were observed in a few fields of processing tomatoes.

Double Streak Virus, Tobacco Mosaic Virus, and leaf mold (*Cladosporium* sp.) plagued several hydroponic tomato growers.

Injury from driving spring rains predisposed onion sets to blast infection (*Botrytis* sp.). Weather conditions also favored development of onion downy mildew caused by *Peronospora destructor*.

Broccoli fields in Floyd and Clark counties in the south and Jasper County in the north were affected with a head rot of unknown cause. Soft rotting bacteria have been isolated from field samples, but these bacteria are believed to play a secondary role. (Unusual atmospheric conditions prior to symptom expression may be responsible for the initial injury.

Agronomic Crops

Diseases-Wheat: Wheat diseases were especially damaging in 1981. While disease losses varied from field to field, the average disease loss for the state was estimated at 20%. The state average yield of 43 bu/A was very good considering the disease pressure. Powdery mildew, *Septoria* leaf blotch, *Septoria* glume blotch, and scab were all present in nearly every field in the state. Leaf rust was also present in nearly all fields late in the season. Powdery mildew and *Septoria* leaf blotch were especially severe in fields planted to susceptible varieties and where high seeding rates (2 bu/A) and high nitrogen rates (90 lb/A or more actual N) were used. In many of these fields, the flag leaves were infected by heading time. Above normal precipitation during flowering throughout most areas of the state provided ideal conditions for the development of scab. In addition, Barley Yellow Dwarf Virus was prevalent in southern Indiana and wheat spindle streak virus occurred throughout the state but was especially evident in the northern part.

Diseases-Corn: In corn, leaf blights were common, but the most damaging corn diseases were the stalk rots and ear rots. Southern corn leaf blight (SCLB) was found throughout the state. This disease may have contributed to increased stalk rot severity, and in some late planted fields in southern Indiana, SCLB was sufficiently severe to cause significant yield reductions. *Bipolaris carbonum*, a foliar pathogen in corn, was found in many seed production fields. Other leaf blights were observed but caused little or no concern, e.g., races 1 and 2 of northern corn leaf blight, common rust, southern rust, and Stewart's bacterial leaf blight. Anthracnose top kill was observed in most areas of the state. *Gibberella*, *Fusarium*, and anthracnose stalk rots were common. *Gibberella* and *Fusarium* stalk rots appeared to be the most severe, with anthracnose stalk rot developing later. Severe lodging occurred in some fields. *Fusarium* and *Gibberella* ear rots were common and widespread. *Gibberella* ear rot was sufficiently severe in some fields to cause swine refusal and other feeding problems. *Diplodia* ear rot was found in several fields in Orange and Washington counties. The disease was severe, affecting 60% of the ears in at least one field. In all observed cases, *Diplodia* ear rot was found in fields where corn followed corn and the previous crop residues remained on the soil surfaces.

TABLE 8. *Agronomic Crops—Diseases and Disorders.*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Triticum (WHEAT)		
Root Rot (see below)	Various (see below)	11
Rhizoctonia	*Rhizoctonia solani*	2
Take-all	*Ophiobolus graminis*	9
Wheat Spindle Streak	Wheat Spindle Streak Virus	9
Barley Yellow Dwarf	Barley Yellow Dwarf Virus	8
Septoria Glume Blotch	*Septoria nodorum*	9
Scab	*Gibberella zeae*	19
Septoria Leaf Blotch	*Septoria tritici*	7
Powdery Mildew	*Erysiphe graminis*	1
Rhizoctonia Leaf Blight	*Rhizoctonia solani*	4
Black Chaff	*Xanthomonas transluscens*	2
Tan Spot	*Helminthosporium sativum*	4
Leaf Rust	*Puccinia tritici*	2
Seedling Blight	*Gibberella zeae*	1
Miscellaneous Disorders		
Inhibited Germination	Soybean residue	1
Chlorosis	Nutrient imbalance	5
Root Restriction	Soil compaction	1
Poor Growth	Desiccation/drought	4
Leaf Discoloration	Frost	1
Avena (OAT)		
Barley Yellow Dwarf	Barley Yellow Dwarf Virus	1
Miscellaneous Disorders		
Herbicide Injury	Atrazine carryover	2
Bleached Heads	Unidentified	1
Sorghum (SORGHUM)		
Miscellaneous Disorder		
Herbicide Injury	Improper Use	1
Zea (DENT CORN)		
Pythium Seedling Blight	*Pythium aphanidermatum*	2
Anthracnose	*Colletotrichum graminicola*	5
Northern Corn Leaf Spot	*Bipolaris carbonum*	5
Southern Leaf Blight	*Bipolaris maydis* (Race 0)	20
Common Smut	*Ustilago maydis*	1
Common Rust	*Puccinia sorghi*	3
Stewart's Blight	*Erwinia stewartii*	6
Chocolate Spot	*Psdeuomonas atrofaciens* pathovar *zeae*	1
Leaf Spot	*Curvularia* spp.	1
Ear Rots (See below)	Various (See below)	19
Fusarium Kernel Rot	*Fusarium moniliforme*	5
Fusarium Kernel Rot	*Gibberella zeae*	11
Kernel Rot	*Cladosporium* spp.	1
Kernel Rot	*Diplodia maydis*	5
Stalk Rots (See below)	Various (See below)	6
Fusarium Stalk Rot	*Fusarium moniliforme*	3
Gib Stalk Rot	*Gibberella zeae*	1
Bipolaris Stalk Rot	*Bipolaris carbonum*	1
Anthracnose Stalk Rot	*Colletotrichum graminicola*	1
Miscellaneous Disorders		
Chlorosis/Striping	Nutrient imbalance	9
Root Restriction	Soil compaction	8
Leaf Spot	Paraquat spray drift	9
Leaf Spot	Environmental	12
Twisted Stem	Mechanical	3
Dieback	Fertilizer burn	2

TABLE 8.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Tall Corn/Short Corn	Environmental factors	1
Herbicide Injury	Improper use	6
Poor Ear Development	Stress factor(s)	1
Leaf Striping	Genetic	2
Glycine (SOYBEAN)		
Rhizoctonia Root Rot	*Rhizoctonia solani*	7
Phytophthora Root Rot	*Phytophthora megasperma* var. *sojae*	2
Pythium Root Rot	*Pythium aphanidermatum*	2
Pod and Stem Blight	*Diaporthe phaseolorum* var. *sojae*	5
Brown Stem Rot	*Cephalosporium gregatum*	5
Brown Spot	*Septoria glycines*	6
Charcoal Rot	*Macrophomina phaseolina*	2
Purple Seed Stain	*Cercospora kikuchii*	1
Anthracnose	*Colletotrichum graminicola*	2
Downy Mildew	*Peronospora manshurica*	4
Sclerotinia Stem Rot	*Sclerotinia sclerotiorum*	4
Stem Canker	*Diaporthe phaseolorum* var. *caulivora*	1
Soybean Cyst Nematode	*Heterodera glycines*	5
Miscellaneous Disorders		
Various Problems	Environmental factors	11
Chemical Injury	Various causes	6
Chlorosis	Nutrient imbalance	6
Root Restriction	Soil compaction	2
Leaf Discoloration	Sunscald	5
Stem/Root Splitting	Stress factor(s)	2
Slime Mold		1
Leaf Spot	Environmental	1
Trifolium (CLOVER)		
Alfalfa Mosaic	Alfalfa Mosaic Virus	2
Witches Broom	Witches Broom Virus	1
Miscellaneous Disorders		
Leaf Discoloration	Fertilizer burn	1
Medicago sativa (ALFALFA)		
Crown/Root Rot Complex	Variety of fungi and poor cultural conditions	20
Sclerotinia Crown & Stem Rot	*Sclerotinia trifoliorum*	2
Spring Blackstem	*Phoma medicaginis*	2
Root Rot	*Pythium* spp.	1
Root Rot	*Phytophthora* sp.	1
Root Rot	*Fusarium* sp.	2
Crown Rot	*Helminthosporium* sp.	1
Anthracnose	*Colletotrichum trifolii*	1
Summer Leaf Spot	*Cercospora* sp.	3
Root Rot	*Rhizoctonia solani*	5
Leptosphaerulina Leaf Spot	*Leptosphaerulina briosiana*	2
Leaf Spot	*Stemphylium* sp.	1
Miscellaneous Disorders		
Chlorosis	Nutrient imbalance	8
Leaf Discoloration	Environmental factors	1
Leaf Purpling	Boron deficiency	2
Root Restriction	Compaction	1
Dactylis glomerata (ORCHARD GRASS)		
Leaf Spot	*Helminthosporium sativum*	1
Festuca (FESCUE)		
Leaf Spot	*Helminthosporium sativum*	1
Miscellaneous Disorders		
Leaf Dieback	Environmental stress	1

TABLE 8.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Leaf Discoloration	Fertilizer burn	1
Phleum pratense (TIMOTHY)		
Miscellaneous Disorder		
Stunted	Nutrient deficiency	1
Sorghum sudanense (SUDANGRASS)		
Miscellaneous Disorder		
Leaf Spot	Paraquat	1

Diseases-Soybean: Soybean planting was delayed to mid-June or later in many areas of the state as a result of the wet weather. *Rhizoctonia* root rot was the most commonly reported disease of seedling and young soybean plants. Brown spot and downy mildew were common mid and late season foliar diseases. Brown spot caused premature defoliation and yield reductions in some fields. *Sclerotinia* stem rot was reported in scattered fields. The disease was severe in a few fields. Brown stem rot was widespread and caused premature plant death. Pulaski county was added to the list of counties where the soybean cyst nematode was found. Pod and stem blight and purple seed stain were common seed diseases, but they were not as severe as might have been expected with the wet weather.

Diseases-Alflafa: *Leptosphaerulina* leaf spot, spring black stem, and anthracnose were widespread in alfalfa fields. However, the most damaging problem was the disease known as crown-root rot complex. The disease was prevalent in numerous fields in the state and especially severe in some eastern and northeastern Indiana fields. The disease reduced stands to subeconomic levels in many fields.

Literature Cited

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Contribution to the Flora of Indiana: Fungi of West-Central Indiana on the Occasion of The Sixth Annual A. H. Smith Great Lakes Foray

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Introduction

Distribution records of fungi, particularly the microfungi are limited. Often distribution records of fungi are limited to sites visited by mycologists. In order to record the distribution of fungi, mycologists and the fungi need to be brought together. The purpose of this study was to organize a group of mycologists, mycophagists and friends to collect all visible fungi from selected sites, to identify the specimens collected and to provide a record of these collections by placing samples in recognized herbaria for future reference.

Study Sites

The sixth Annual Great Lakes Foray based at Indiana State University, Terre Haute was held on September 19 and 20, 1980. Three locations were visited, designated here and in the list of fungi by letters. Kiewig Woods (K) near the Wabash River in West Terre Haute is an area of ridges dominated by Beech-Maple and ravines dominated by Oak-Hickory and was deeded to the Indiana Nature Conservancy in 1979. Portland Arch (PA) in Fountain County Indiana is an area of sandy ridges and bottom land and ravines cut by Bear Creek. The diversity of soil and topography is matched by a diversity of plant types and associated fungi. The forest cover is mixed hardwood and pine. Portland Arch is under the protection of the Indiana Department of Natural Resources, and the Nature Conservancy; and the Field Campus (FC) of Indiana State University, Terre Haute is located in Brazil, Indiana. Stripmining until 1867 left 5 lakes totaling 35 acres, with adjacent mixed hardwood woodland and creek bottom, and field sites. These stripmine lakes are mainly fed by an underground water supply. Some of the flat area had been farmed. Since I.S.U. purchased the area in 1964, it has been used for science education, field biology, recreation and recreation education.

Special appreciation is extended the Foray participants who helped collect, and identify the fungi; Charles B. Arzeni, I. L. Conners, Fred Cizek, J. L. Crane, Robert V. Gessner, Beverly Holler, James Holler, Nina Johnson, John McCain, Bill McKnight, Alan Parker, Norb Rolnicki, Stephen Saupe, Wesley Whiteside and John Wilcott. In addition to Wesley Whiteside, A. H. Smith provided professional identification of macrofungi such as the mushrooms, J. L. Crane provided identification of Hyphomycete microfungi and John McCain collected and identified the rusts. The Foray was organized and directed by Jean Schoknecht.

Results

Some of the interesting finds were the species of Cortinarius under the pine at Portland Arch. *Lactarius indigo* (Schw.) Fr., which is considered to be common in the southeastern United States and rare elsewhere was also identified on the 1970 Indiana Foray which took place near Bloomington in conjunction with the Mycological Society of America annual meetings. All specimens collected on this Foray which were reported from the Indiana Foray List (1) are indicated by an asterisk. Some of these Fungi are commonly collected throughout the west-central

section of Indiana and east-central Illinois such as *Scutellinia scutellata* (L. ex. Fr) Lambotte and *Bisporella sulfurina* (Quel.) Carpenter.

The fungi which were collected are listed alphabetically within major groups. The collection is identified by herbarium numbers which refer to the Illinois Natural History Survey number (ILLS) and duplicate specimens are in Indiana State University's Herbarium (TER). Some rusts are only housed at Purdue and the numbers are preceeded by the PUR designation. The herbarium numbers are followed by the location, Kiewig woods (K), Portland Arch (PA) and the I.S.U. Brazil Field Campus (FC).

MYXOMYCETES

Arcyria denudata (L.) Wettst.* 40721 - (K), 40725 - (PA), 41135 - (K); *Arcyria incarnata* (Pers.) Pers. 40647 - (PA); *Arcyria nutans* (Bull.) Grev. 40744 - (PA); *Hemitrichia stipitata* (Massee) Macbr. 40751 - (PA), 40752 - (PA); *Metatrichia vesparium* (Batsch) Nann-Brem. 40681 - (PA), 40756 - (PA); *Perichaena corticalis* (Batsch) Rost. 40760 - (PA).

ZYGOMYCETE

Syzygites megalocarpus, Ehrenberg ex Fr.,* 40740 - (PA).

HYPHOMYCETES

Alysidium aureofulvum (Cooke & Ellis). 40644 - (PA); *Bactridiopsis* (sp. I)* 41136 - (K), 42167 - (FC), 41128 - (K); *Bispora betulina* (Corda) Hughes. 40648 - (PA); *Brachysporium nigrum* (Link) Hughes. 40630 - (FC); *Calcarisporium arbuscula* Preuss 40631 - (FC); *Cladobotryum verticillatum* (Link ex S.F. Gray) Hughes. 42161 - (K) on old Agaricales, 41130 (K) on *Lactarius* sp; *Clonostachys compactiuscula* (Sacc.) D. Hawksworth & W. Gams. 40632 (FC); *Conioscypha varia* Shearer 40626 - (K); *Crinula calicuformis* Fries. 41133 - (K), 41134 - (K); *Dendryphiopsis atra* (Corda) Hughes. 40732 (PA) on wood; *Monodictys lepraria* (Berk.) M.B. Ellis. 42354 - (PA) on wood; *Pseudobotrytis terrestris* (Timonin) Subramanian. 40763 - (PA); *Spadicoides bina* (Corda) Hughes. 40766 - (PA); *Stilbella tomentosa* (Schrad ex Grev.) Bres. 41153 - (FC) on *Metatrichia vesparium*; *Torula herbarum* (Pers.) Link ex S.F. Gray. 40628 - (K); *Trichoderma hamatum* (Bon.) Bain. 40643 - (FC); *Verticillium rexianum* (Sacc.) Sacc. 40769 - (PA) on *Stemonitis fusca* Roth, 41152 - (FC) on *Arcyria pomiformis*, 41137 - (K) on *Didymium* sp, 41140 - (K) on *Stemonitis splendens*.

ASCOMYCETES

Bisporella citrina (Batsch ex Fries) Korf & Carpenter.* 40726 - (PA), 40745 - (PA), 40746 - (PA), 41129 - (K); *Bisporella sulfurina* (Quel.) Carpenter. 40747 - (PA); *Ciboria Peckiana* (Cke) Korf.* *forma gigaspora* (Korf) Korf* listed in 1970 Foray as *Rutstroemia macrospora* (PK) Kanouse. 42575 - (PA); *Creopus gelatinosus* (Tode ex Fr.) Link. 40731 - (PA); *Diatrypella nigro-annulata* Grev. Nit. 40733 - (PA) on *Fagus americana* Sweet; *Glonium abbreviatum* (Schw.) Lohman. 41132 - (K); *Glonium lineare* (Fries) deNotaris. 40635 - (FC);*Hyalinia rubella* (Fries) Nannfeldt. 40753 -(PA), 40754 - (PA); *Holwaya mucida* (Schulzer) Korf and Abawi. 42572 - (K), 42402 -(K); *Hymenoscyphus fructigenus* (Bulliard & Merat) S.F. Gray. 41139 - (K) on *Carya* sp. shells; *Hypocrea rufa* (Pers. ex Fr.) Fr.* 40734 - (PA) decayed wood, 40755 - (PA); *Hypoxylon cohaerens* Pers. ex Fr. 40670 - (PA) on decayed *Fagus americana* Sweet log, 40735 - (PA), 41126 - (K) branch; *Leotia lubrica* (Scop.) Persoon.* 40722 - (K), 42411 - (PA), 42412 - (PA); *Mollisia caespiticia* Karsten. 40736 - (PA); *Mollisia* cf. *encoelioides* Karst. 42301 - (FC); *Orbilia coccinella* (Sommerf.)

Fries. 40790 - (PA); *Orbilia luteo rubella* (Nylander) Karsten. 40758 - (PA), 41150 - (FC), 42302 - (K); *Orbilia xanthostigma* (Fries) Fries.* 40759 - (PA), 42303 - (K); *Peziza badia* Pers. 40737 - (PA) sandy soil & wood; *Rutstroemia luteovirescens* (Roberge) White 42148 - (FC); Sarcoscypha *coccinea* (Fries) Lambotte. 40642 - (FC), 40693 - (PA); *Scutellinia scutellata* (L. ex Fr.) Lambotte.* 40694 - (PA), 40765 - (PA); *Strossmayeria basitrichia* (Sacc.) Dennis. 40768 - (PA).

BASIDIOMYCETES

Agaricus placomyces Peck.* 40667 - (PA); *Amanita fulva* Pers. 40724 - (PA); *Amanita rubescens* (Fr.) S.F. Gray. 40645 - (PA), 42361 - (PA); *Amanita vaginata* (Fr.) Vitt. 40646 - (PA); *Boletus castaneus* Bull. 40649 - (PA), 40668 - (PA); *Boletus curtissii* Berk. 40621 - (K); *Boletus felleus* Bull. Var. minor, Coker & Beers. 40650 - (PA); *Boletus rubellus* Krombolz. 42201 - (PA); *Boletus rubropunctus* Peck. 40651 - (PA), 42346 - (PA); *Boletus subsanguineus* Peck. 42345 - (K); *Calocera cornea* (Fr.) Loudon.* 40748 - (PA); *Cantharellus cibarius* Fries.* 40652 - (PA), 40653 - (PA); *Cantharellus cinnabarinus* Schweinitz. 40654 - (PA), 40655 - (PA), 42366 - (PA), 42367 - (PA); *Cantharellus lateritius* Berkeley. 40656 - (PA); *Clitocybe adirondackensis* (Peck) Saccardo. 40727 - (PA), 40728 - (PA); *Clitocybe nuda* (Fr.) Bigl. & Sm. 40657 - (PA); *Clitocybe odora* (Fr.) Kummer.* 40623 - (K), 40658 - (PA); *Coleosporium asterum* (Diet) Syd. 40794 PUR 65989 - (PA) Uredinia on *Solidago casia* L., 40797 PUR 65987 - (K) Uredinia some Telia on *Solidago altissima* L.; *Coleosporium vernoniae* Berk & Curt. 40795 - (K) Uredinia on *Vernonia altissima*, 80034, PUR 65988; *Collybia dryophila* (Fr.) Kummer.* 40624 - (K), 40659 - (PA), 40660 - (PA), 42376 - (PA); *Collybia radicata* (Fr.) Quel. 40625 - (K), 40661 - (PA), 40729 - (PA); *Cortinarius alboviolaceus* (Fr.) Kummer. 40662 - (PA), 42391 - (PA); *Cortinarius claricolor* Fries. 42348 - (PA); *Cortinarius semisanquineus* (Fr.) Gill. 40663 - (PA), 42392 - (PA); *Cortinarius violaceus* (Fr.) Fries. 40664 - (PA); *Craterellus cornucopioides* Pers. 40730 - (PA), 41145 - (PA), 42350 - (PA), 42393 - (PA); *Craterellus cantharellus* (Schw.) Fries. 41144 - (PA), 42347 - (PA), 42394 - (PA), 42353 - (PA); *Crepidotus mollis* (Fr.) Staude. 40633 - (FC); *Crucibulum vulgare* Tul. 40665 - (PA), 42574 - (PA); *Cyathus striatus* Per.* 40634 - (FC); *Daedalea confragosa* Bolt. ex Fr. 40749 - (PA) decayed branches, 40750 - (PA); *Dentinum repandum* (Fr.) S.F. Gray.* 42349 - (PA) soil with moss, 42397 - (PA) soil with moss; *Excidia glandulosa* Bull ex. Fr. 40666 - (PA); *Fomes everhartii* (Ell & Gall.) Von Schrenk & Spauld. 42307 - (FC); *Hygrocybe coccinea* (Fr.) Kummer. 40636 - (FC), 40669 - (PA); *Hygrophorus coccineus* (Fr.) Fr. 42403 -(FC); *Laccaria laccata* (Fr.) Berk & Br.* 40671 - (PA) sandy ridge, 42407 - (PA) sandy ridge; *Lactarius canadensis* A.H. Smith. 41143 - (PA); *Lactarius corrugis* Peck. 40672 -(PA); *Lactarius luteolus* Peck. 40673 - (PA); *Lactarius indigo* (Schw.) Fries.* 40637 -(FC), 40638 - (FC), 42408 - (FC); *Lactarius neuhoffii* Hes. & Sm. var. *neuhoffii*. 40674 -(PA); *Lactarius psammicola* 42202 - (FC); *Lactarius pubescens* Fr. var *pubescens*. 42352 - (PA); *Lactarius subvellereus* Peck. var subdistans Hes. & Sm. 40676 - (PA); *Lentinellus ursinus* (Fr.) Kuehn. 42410 - (PA) Rotten log; *Lenzites trabea* Fr. 42589 -(PA); *Lepiota acutesquamosa* (Weinm.) Kummer.* 42415 - (PA); *Lepiota americana* Peck. 40677 - (PA); *Leucopaxillus paradoxus* (Cost. & Duf.) Bours. 41146 - (PA); *Lycoperdon perlatum* Pers.* 40678 - (PA), 42469 - (PA); *Marasmius delectans* Morg.* 42424 - (K) oak leaves, 41142 - (K); *Marasmius siccus* (Schw.) Fries. 40679 -(PA) leaf litter, 40680 - (PA) oak leaf litter, 42425 - (K); *Mycena galericulata* (Fr.) S.F. Gray. 42200 - (K); *Mycena haematopus* (Fr.) Kummer.* 40639 - (FC); *Mycena leaiana* (Berk.) Sacc. 40682 - (PA) rotten wood; *Mycena luteopallens* (Peck) Sacc. 40640 -(FC), 40683 - (PA), 40757 - (PA), 41127 - (K); *Oxydontia chrysorhiza* (Torrey) Rogers & Martin.* 42308 -(FC) decayed leaves; *Phellodon*

niger (Peck) Banker. *var. alboniger* (Peck) H. 40684 - (PA); *Phlebiella vaga* (Fr.) Karsten. 41142 - (K) decayed wood; *Phleogena faginea* (Fries) Lind. on *Fagus americana Sweet.* - (PA) 40685; *Pleurotus ostreatus* (Fr.) Kummer.* 40686 - (PA); *Polyporus adustus* Willd. ex. Fr. 41151 - (FC); *Polyporus cinnabarinus* Jacq. ex Fries. 40641 - (FC), 40687 - (PA), 42443 - (PA); *Polyporus frondosus* 42466 - (PA), 42351 - (PA); *Polyporus gilvus* (Schw.) Fries. 40761 - (PA); *Polyporus tulipiferae* (Schw.) Overholts. 40762 - (PA); *Polyporus versicolor* L. ex. Fr. 40688 - (PA); *Pterula plumosa* (Schw.) Fr. 40764 - (PA); *Puccinia bolleyana* Sacc. PUR 65994 - (K) Telia, (some uredinia on *Carex frankii* Kunth); *Puccinia dioicae* P. Magn. PUR 65993 - (K) PUR 65992 - (K) Uredinia on Viola sp; *Pucciniastrum hydrangeae* (Magn.) Arth. 40796 - Uredinia and Telia on *Carex annectans* (Bickn.) Bickn; *Puccinia violae* (Schum.) Oc. (PA) uredinia on *Hydrangea arborescens*, PUR 65990 - (PA) Uredinia on H. *arborescens*, PUR 65986 - (K) Uredinia (some Telia); *Ramaria aurea* (Fr.) Quelet. 40738 - (PA), 40739 - (PA); *Ramaria botrytis* (Fr.) Ricken. 40689 - (PA); *Ramaria obtusissima* (Peck) Corner. 40690 -(PA); *Rhodophyllus griseus* (Peck) 40691 - (PA); *Russula paludosa* Britzelmayr. 40627 -(K), 40692 - (PA); *Scleroderma citrinum* Pers. 42591 - (PA); *Stereum ostrea* (Blume & Nees ex Fr.) Fr.* 41138 - (K); *Sphaerobolus stellatus* Tode. 40723 - (FC); *Strobilomyces floccopus* (Fr.) Karst. 41147 - (PA); *Suillus americanus* (Pk.) Snell. 42457 - (FC); *Thelephora intybacea* Fr. 42590 - (PA) *Tomentella ferruginosa* (Pers.) Schroet. 41154 - (FC) rotten wood; *Tomentella rubiginosa* (Bres.) R. Maire. 40695 -(PA); *Tremellodendron Schweinitzii* (Pk.) Atkinson.* 40741 - (PA), 40742 - (PA); *Tyromyces guttulatus* (Peck) Murrill. 40743 - (PA) on decayed wood.

The following species were reported but specimens were not preserved. *Amanita brunnescens* Atk.* - (PA), *Amanita flavoconia* Atk.* - (PA); *Clitocybe caespitosa* Pk. - (K); *Clitocybe multiceps* Pk.; *Craterellus foetidus* A.H. Smith. (PA); *Dacryopinax elegans* (B & C) Martin. (K); *Entaloma rhodopodium* Fr. (K); *Fomes fraxinophilus* (Pk) Sacc. (PA); *Geastrum morgani* Lloyd (PA); *Heliomyces nigripes* (Schw.) Morg. (K); *Hydnum imbricatum* Fr. (PA); *Lactarius volemus* Fr.* (PA); *Lentinellus ursinus* (Fr.) Kueh.; *Marasmius rotula* Fr. (K); *Russula virescens* Fr. (PA).

Many of the fungi were growing on decaying leaf litter or rotten wood. Although most of the species of *Mycena* were ubiquitious wood decomposers *Mycena luteopallens* (Peck) Sacc. which is always found growing on walnut, *Carya*, sp. shells is interesting because of its apparently restricted substrate. *Rutstroemia luteovirescens* (Roberge) White was collected on petioles of much decomposed leaves and leaves of ash, Fraxinus, were identified as substrate for *R. luteovirescens*. Some of the mushrooms were probably mycorrhizal, for example, the three species of *Cortinarius* were only collected near pine.

Also of interest are the mycoparasites *Verticillium rexianum* (Sacc.) Sacc. on various species of Myxomycete, *Stibella tomentosa* (Schrad.) ex Bres. also on Myxomycetes and *Syzgites megalocarpus* Ehrh. ex Fr. on mushrooms.

Summary

In all, six Myxomycetes, one Zygomycete, seventeen Hyphomycetes, twenty-three Ascomycetes and eighty-seven Basidiomycetes are recorded and documented with herbarium samples. A few fleshy fungi were not preserved and are listed as reported without herbarium specimens.

Literature Cited

COOKE, WM. BRIDGE, 1975. The 1970 Indiana Foray. Mycologia 67:1065-1071.

CELL BIOLOGY

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ABSTRACTS

S-Adenosyl-L-Methionine Decarboxylase Activity in Mouse Mammary Adenocarcinomas. BETH AUGER and ALICE BENNETT, Department of Biology, Ball State University, Muncie, Indiana 47306.——In this study the activity of SAMD in non-tumorous mammary tissue and mammary adenocarcinomas in Strong Strain A female mice was determined.

S-adenosyl-L-methionine decarboxylase (SAMD) is one of the biosynthetic enzymes for the polyamines spermine and spermidine. SAMD activity is known to increase with the increase in intracellular concentration of spermidine in lactating mammary tissue in mice, is known to increase in rapidly proliferating tissues like regenerating rat liver and developing chick embryo, and has recently been found to increase in virus transormed cells.

The soluble particle-free supernate was isolated from prelactating and malignant mammary tissue by centrifugation. SAMD was assayed by liquid scintillation spectrometry using radioactively labeled (^{14}COOH)-S-adenosyl-L-methionine as the substrate to produce $^{14}CO_2$ as the measurable end-product of the enzyme catalyzed reaction.

The activity of SAMD in adenocarcinomas was found to be significantly higher than in normal tissues. The relationship between this activity and the types of phospholipids found in mammary tumors will be discussed.

Proteins Which Support Growth of *Paramecium multimicronucleatum* in Chemically Defined, Axenic Culture. THOMAS A. COLE, NICHOLAS E. LEAL and WILLIS H. JOHNSON, Department of Biology, Wabash College, Crawfordsville, Indiana 47933.——In 1980 this laboratory reported the culture of *Paramecium multimicronucleatum* on a chemically defined, axenic medium. Since that time, the supplier of chicken ovalbumin (5X crystallized) has discontinued this product which was used in culture for several years. In this report we detail attempts to substitute ovalbumins from other suppliers and a variety of other proteins (hemoglobin, myoglobin, ribonuclease, lysozyme, bovine serum albumin, concanavalin A, pepsin, trypsin, chymotrypsin) with and without added amino acids for the original ovalbumin preparation. Those proteins which support growth in an otherwise complete medium are concanavalin A, bovine serum albumin, myoglobin, hemoglobin and pepsin. Without added amino acids, three proteins (bovine serum albumin, myoglobin and hemoglobin) support growth of this ciliate through seven serial transfers.

Separation of Naturally Occurring Forms of Vitamin A by Reverse Phase HPLC in Tumor Bearing Rats. WILLIAM C. DOUGLASS, RICHARD E. ZOLLINGER and DOROTHY M. MORRÉ, Department of Foods and Nutrition, Purdue University, West Lafayette, Indiana 47907.——Vitamin A and its derivatives have been

demonstrated to have a chemo-preventative effect on development of cancers in a number of experimental animals and organ cultures. In this study, we used reverse phase high pressure liquid chromatography (HPLC) to separate the naturally occurring forms of vitamin A in livers and tumors when rats were fed varying levels of vitamin A as retinyl acetate. Male weanling rats were fed basal AIN-76A diets supplemented with zero, adequate (4,000 IU/kg diet) or excess (100 X adequate) amounts of vitamin A. After two weeks, the rats were injected with transplantable hepatocellular carcinomas induced in syngeneic donor rats by the carcinogen, N-2-fluorenylacetamide. The liver and tumor samples were extracted by chloroform-methanol and aliquots were chromatographed on a C_{18} reverse phase HPLC column using acetonitrile—1% ammonium acetate in water as the mobile phase. The retention times were approximately 5, 9, 11, 14 and 35 minutes, respectively, for retinoic acid, retinol, retinal, retinyl acetate and retinyl palmitate. The amounts of vitamin A in the tissues closely paralleled that fed in the diet. The HPLC profiles showed a general pattern of separation for all levels of vitamin A to be a small amount of retinoic acid and the fed retinyl acetate, moderate amounts of retinol and increased amounts of the various retinyl esters. Additional work is being done to determine the ester forms present in blood, particularly in the excess group where the observed symptoms of hypervitaminosis A toxicity are thought to be due to the circulating unbound retinyl esters.

Ultrastructural Correlates of the Spitzenkörper Core in Rhizoctonia solani. STANLEY N. GROVE, Goshen College, Goshen, Indiana 46526.——Light and electron microscopic evidence indicates that a phase contrast—dark group of closely asociated apical vesicles disappears immediately in hyphae of *R. solani* when polar growth is interrupted by the application of cytochalasins. When slide cultures are perfused with cytochalasins (CA or CE at 1 ug/ml in 0.1% DMSO) polar growth stops in 20-60 seconds accompanied by the loss of the dark portion of the Spitzenkörper (apical body). In control cultures perfused with 1% DMSO hyphae continue growing at pretreatment rates and maintain the typical morphology. In treated hyphae the phase contrast—bright core or inner zone of the Spitzenkörper enlarges and remains visible in the apical cytoplasm for several minutes. It retracts from the extreme apex and moves about in the apical cytoplasm closely associated with numerous mitochondria. The ultrastructural correlate of the persistent core may include tubules of endoplasmic reticulum which enlarge and become more prominent after treatment and cessation of apical growth.

Role of Calcium-binding Protein in Neuronal Function. ZAFAR IQBAL, Department of Physiology and Biochemistry and Medical Biophysics Program, Indiana University School of Medicine, Indianapolis, Indiana 46223.——Calcium plays an important role in the regulation of a large number of cellular processes including the axoplasmic transport of materials in nerve fibers. Recent observations have indicated that the action of calcium is mediated through a calcium-binding protein now known as calmodulin. We have purified and characterized this protein from mammalian nerve and shown that the protein is transported in nerve fibers. In the presence of micromolar (10^{-6}M) concentration of Ca^{2+}, the protein was found to activate cyclic nucleotide phosphodiesterase (PDE), an enzyme responsible for the hydrolysis of ATP to liberate energy needed for the transport process. Stellazine, which binds to calmodulin blocks the activation of PDE and Ca-ATPase and axoplasmic transport as well. These observations suggest that calmodulin plays an important role in the axoplasmic transport which is an essential neuronal function required for the maintenance of normal physiological conditions.

Gamma Glutamyl Transpeptidase Activity Not a Reliable in Vitro Marker of Transformation in Cell Lines Derived from a Hepatocellular Carcinoma. LINDA B. JACOBSEN and PAMELA J. SWIATEK, Purdue Cancer Center, Purdue University, West Lafayette, Indiana 47907.——Many markers have been proposed to identify transformed cells in culture in order to avoid the inoculation of susceptible animals and the wait for tumor development. Anchorage independent growth (growth in soft agar) correlates with tumorigenicity in most systems, while the reliability of other markers depends on the system. Gamma glutamyl transpeptidase (γGT) activity has been used in many *in vivo* studies to monitor tumor progression in hepatocellular carcinogenesis in rats. When transformed ceil lines derived from liver tissue were tested they also were found to contain γGT activity. Thus this marker has been proposed as a new method to identify transformed hepatocytes in culture.

A primary hepatocellular carcinoma was removed from a rat fed 2 acetylamino fluorene. A portion of the tissue was minced and inoculated into syngeneic recipients. The RLT_1 poorly differentiated metastatic transplantable tumor line was developed from this and was described previously. The remainder of the primary tumor was used to initiate an *in vitro* cell line, P CCL-H_2. Unique cell lines were derived from the parental P CCL-H_2 line by passaging through either syngeneic recipients or soft agar. There was no correlation between γGT and ability to grow in soft agar in these related cell lines. This suggests that γGT activity is not a reliable marker for transformation, and must, at present, be used in combination with other *in vitro* markers to evaluate the transformed phenotype.

Thioesterase II in Cell Free Fractions of Adenocarcinomas and Normal Mouse Mammary Tissue. ALBERT KENDRA and ALICE BENNETT, Department of Biology, Ball State University, Muncie, Indiana 47306.——Normal and tumorous rodent mammary tissue synthesize predominantly long chain fatty acids (C_{14-18}). The ability of rodent lactating tissue to synthesize medium chain fatty acids (C_{8-12}) correlates with the presence of thioesterase II, a chain terminating enzyme.

This research studied the ability of thioesterase II to affect a change in the types of fatty acids synthesized by cell free fractions of tumor tissue.

Thioesterase II was obtained by ammonium sulfate precipitation from the particle free supernatent and assayed spectrophotometrically. The fatty acids synthesized by the microsomal and soluble fraction of tumor, with and without thioesterase II were separated by gas liquid chromatography and the amount of incorporation of ^{14}C-acetyl CoA was determined by liquid scintillation spectroscopy.

It was concluded that the normal and tumor fatty acids synthesized *de novo* were similar in distribution. The addition of thioesterase II to tumor tissue incubations did not affect a statistically significant change ($P < 0.05$) in fatty acid distribution.

It appears that thioesterase II does not contribute significantly to the distribution of fatty acids in tumor tissue, and that the major functional enzymes for *de novo* synthesis are acetyl CoA carboxylase and fatty acid synthetase.

Localization of Constitutive Heterochromatin in Phlox drummondii. ROMESCH C. MEHRA and GEORGE MARTIN, Department of Biology, Indiana University at South Bend, South Bend, Indiana 46615 and THOMAS FOGLE, Department of Biology, St. Mary's College, South Bend, Indiana 46556.——Several roles have been suggested for constitutive heterochromatin and its general correspondent, satellite DNA, in chromosome mechanics. Consequently, it has become important to localize con-

stitutive heterochromatin on chromosome complements of different taxa. *Phlox drummondii* (2n = 14), a member of the second largest genus in the family Polemoniaceae and native to Eastern and North Central Texas, was investigated. The modified BSG technique was utilized to localize constitutive heterochromatin. C-bands were more pronounced in the centromeric regions than the interstitial and terminal portions of the chromosomes. A total of 34 positively stained C-bands were delineated. On the basis of these bands and the length and centromeric index, a karyotype of the taxa has been prepared. The centromeric regions were more resistant to chemical degradation of the chromosomes which suggests that two types of constitutive heterochromatin are present.

Work supported by Grant in Aid of Research from Indiana University at South Bend.

Effects of Vitamin A on Various Hematological Parameters of Rats Bearing Tumors. DENISE E. MORGAN, DOROTHY M. MORRÉ and GARY R. MATYAS, Departments of Foods and Nutrition and Biological Sciences, Purdue University, West Lafayette, Indiana 47907.——Patients with malignancies may have coagulative properties which differ from those of normal individuals. Previously, we have shown that vitamin A has the ability to prevent or alter the course of tumor establishment or metastasis in experimental tumorigenesis (J. Nutr. 110, 1629, 1980). It is not known to what extent this effect may be due to changes in hematological properties. In the present study, male weanling rats were fed diets containing either adequate (4,000 IU/kg diet) or excess (100 X adequate) amounts of vitamin A for two weeks. Then one-half of the rats in each group were injected with transplantable hepatocellular carcinomas induced in syngeneic donor rats by the carcinogen, N-2-fluorenylacetamide while the other half were not injected and served as positive controls. Hematological properties monitored included bleeding times, numbers of red blood cells, numbers of white blood cells, hematocrit, hemoglobin concentration and prothrombin rate. Tumors in the excess group were markedly smaller than those in the adequate group while livers of tumor bearing animals, in general, were larger than those of non-tumor bearers. Rats with tumors both in the excess and adequate groups exhibited below normal bleeding times. The excess groups, both with and without tumors, had slightly higher prothrombin rates than those in the adequate groups. Other hematological parameters were much less affected. Supported in part by Phi Beta Psi.

Response of Rat Liver Golgi Apparatus to the Sodium Ionophore Monensin. D. JAMES MORRÉ, S. PHANEUF, A. BEAUDOIN and H. H. MOLLENHAUER, Purdue University, University of Sherbrooke and Veterinary Toxicology and Entomology Research Laboratory, College Station, Texas.——Monensin, an antibiotic and ionophore, exhibits a high and specific complexing affinity for sodium ions. Among a variety of cellular effects of the compound is a tendency to inhibit Golgi apparatus-mediated phenomena. Associated with these inhibitions is a swelling of one or more intercalary Golgi apparatus cisternae. Results will be reported concerning effects of monensin on ultrastructure of isolated Golgi apparatus with emphasis on cisternal swelling.

A Survey of Selected Blood Parameters in Rats Bearing Transplanted Tumors. MASAME NAKANI, DENISE MORGAN, DOROTHY M. MORRÉ and D. JAMES MORRÉ. Purdue University, West Lafayette, Indiana 47907.——Rats bearing both metastatic and nonmetastatic transplantable hepatomas and squamous cell carcinomas were analyzed for blood coagulation times and various other blood parameters. The general tendency was for tumor bearing animals to exhibit shortened coagulation

times relative to normal animals without tumors but with reduced platelet numbers and reduced fibrinogen levels. Approximately ⅓ of the animals bearing non-metastatic tumors or bearing tumors where metastasis had not occurred exhibited greatly increased coagulation times. Of these, all but one had markedly reduced platelet numbers and fibrinogen levels. Blood calcium and partial prothrombin times were not markedly affected by tumor presence. The shortened coagulation times of tumor bearing rats showed no simple correlation with tumor size or growth rate and preliminary results suggests that they may result from overproduction of one or more clotting factors.

Protein Kinase Activities Elevated During Hepatocarcinogenesis Induced by 2-Acetylaminofluorene in the Rat. JEAN ROSSIER, SANDRA SCHILLER-SMITH and D. JAMES MORRÉ. Department of Medicinal Chemistry and Pharmacognosy and Purdue Cancer Center, Purdue University, West Lafayette, Indiana 47907.——Hepatocarcinogenesis in the rat induced by the carcinogen 2-acetylaminofluorene is accompanied by a cascade of metabolic changes leading eventually to a loss of complex cell surface glycoconjugates and altered social behavior. The changes are cyclic and, for the first two major cycles at least, elevations in cyclic nucleotide independent protein kinases of the cytoplasm mark the beginnings of each cycle. To investigate the kinase changes in more detail, the cytoplasmic protein kinase activities were analyzed by chromatography on phosphocellulose at various times during a 50 day continuum of oral carcinogen administration. The results indicate that the elevations involve one or more specific kinases of relatively high molecular weight rather than an overall elevation of the complete kinase spectrum.

Chronology of Protein Kinase and Cyclic Nucleotide Changes During 2-Acetylaminofluorene Induced Hepatocarcinogenesis in the Rat. SANDRA SCHILLER-SMITH, DAVID NOWACK, WILLIAM L. ELLIOTT, PETER F. HEINSTEIN and D. JAMES MORRÉ, Department of Medicinal Chemistry and Pharmacognosy and Purdue Cancer Center, Purdue University, West Lafayette, Indiana 47907.——Livers of rats fed the carcinogen 2-acetylaminofluorene were analyzed for activities of both nuclear and cytoplasmic protein kinases as part of a more detailed study to establish the sequence of biochemical events accompanying tumorigenesis. Endogenous activities were determined with ^{32}P-ATP as substrate and casein or histone were added as co-substrates for determination of exogenous activities. Nuclear protein kinases, with exogenous histone or casein as substrate, were stimulated during the first week of carcinogen administration only. Protein kinases of the cytoplasm yielded maxima at about 25 and 42 to 49 days after the beginning of carcinogen administration. Cyclic AMP levels rose steadily to an approximately 4-fold elevation by day 49 in the livers of the animals receiving carcinogen with the increase beginning prior to the development of visible nodules (at about day 28). The findings provide further evidence for a biochemical cascade in hepatocarcinogenesis and provide useful reference and comparison points for more detailed investigations of individual protein kinases.

Changes in Cytosolic Calcium During Stimulus-secretion Coupling in Mouse Pancreatic Acinar Cells. ROBERT J. STARK, Department of Zoology, DePauw University, Greencastle, Indiana 46135 and J. O'DONERTY, Department of Physiology, Indiana University School of Medicine, Indianapolis, Indiana 46223.——In the exocrine pancreas, natural secretagogues act at the serosal surface of the acinar cells while stimulating fluid and enzyme release from the lumenal surface. As changes in cytosolic calcium ([Ca]i) have been proposed to mediate this process, Ca-selective and conventional microelectrodes were used to examine the relationship between

the secretory response and [Ca]i. By continuously measuring the acetylcholine (ACh) induced changes in intracellular potentials, we determined the effect of varying the stimulus conc. on [Ca]i and secretion. Stimulation with conc. of ACh ranging from 10^{-8}M to 10^{-5}M increased [Ca]i from 0.4 μM to between 0.5 and 1.0 μM. ACh-stimulation of amylase release also followed a definite dose response curve with maximal secretion at 10^{-7}M ACh. Increasing the stimulus concentration above the optimal conc. reduced enzyme release to near basal levels. Use of the Ca-ionophore A23187 mimicked the action of ACh on both enzyme release amd [Ca]i during stimulation of pancreatic acinar secretion and provide further evidence in support of the concept that [Ca]i mediates stimulus-secretion coupling in these cells. Supported by USPHS NIH AM 26246.

Insulin Control of Transplasma Membrane NADH Dehydrogenase. I.L. SUN and F.L. CRANE, Department of Biological Sciences, Purdue University, West Lafayette, Indiana.——Plasma membranes from many animal cells have been shown to contain NADH dehydrogenase. The maximum plasma membrane NADH dehydrogenase activity is seen with ferricyanide as electron acceptor. Using oriented vesicles of erythrocyte membranes it can be shown that there are three types of NADH ferricyanide reductase activities. One is on the outside of the membrane, another is exclusively inside and the third is transmembranous. The transmembrane activity can be measured using intact cells by measuring external ferricyanide reduction since ferricyanide is impermeable. Insulin at physiological concentration partially inhibits (20%) of the activity of open membranes, but it gives up to 45% inhibition of the exclusively transmembrane activity measured with whole cells. Insulin controls this transmembrane activity which can cause proton movement or membrane potential changes. Maximum inhibition with pig erythrocytes is at 20 μU insulin per ml.

Effect of Retinol on Sister Chromatid Exchanges in Chinese Hamster V79 Cells Treated with Cyclophosphamide. JAMES C. TAN, Department of Biology, Valparaiso University, Valparaiso, Indiana 46383.——Sister chromatid exchanges (SCE), observed through the fluorescence plus Giemsa technique, was used to study the inhibitory action of retinol (RA, 32 mcg/ml) on SCE frequency in cultured V79 cells, treated for one hour with the indirect mutagen cyclophosphamide (CPP, 3mcg/ml) and activated S9 mix, after two rounds of DNA duplications. The induction of SCE by CPP + S9 was either preceded or followed by one hour of retinol treatment. Preliminary results indicate that the treatment combinations CPP + S9, RA + (CPP + S9) and (CPP + S9) + RA showed significantly higher frequencies of SCE than the controls (none or S9 only). Furthermore, both the treatment combinations with retinol showed significantly fewer SCE than the CPP + S9 combination, which suggest an inhibitory effect. However, the SCE frequencies of the treatment combinations with retinol introduced before and after the CPP + S9 induction are not statistically different. This result suggests that the inhibitory action of retinol is not so much affected by whether it is present before or after the mutagenic induction by CPP.

Hormonal Control of a Transplasmamembrane Electron Transport System in Plant Cells

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Introduction

Evidence has been presented for the presence of an electron transfer system in the plasma membrane of plant cells (1, 2). The system has been proposed as a transmembrane system that transfers electrons from internal reducing compounds to electron acceptors located external to the cell. Addition of external electron acceptors results in net proton release from the cells. The extracellular reduction of ferricyanide has been shown not to be due to the release of a reducing compound from the cell or to ferricyanide (FeCN), which is a membrane impermeable acceptor, penetrating or being transported into the cells.

The presence of plasma membrane electron transfer seems to be a ubiquitous feature of the plasma membrane of all organisms (7). Electron transfer in mammalian plasma membrane is well established and shows hormone control for FeCN reduction, both with isolated membranes when NADH-FeCN reductase is measured and with intact cells when external FeCN reduction (without NADH addition) is measured (3, 6, 9). A system for electron transfer to external acceptors has been described by Crane and collaborators using yeast (4). Here we present results showing a hormonal control of plasma membrane electron transfer in carrot cells.

Materials and Methods

A carrot cell culture line, obtained from Drs. P. M. Hasegawa and R. A. Bressan of the Purdue Horticulture Department, was grown in liquid suspension culture. Cells were harvested in the logarithmic phase of growth and washed with "assay solution": 0.1 M sucrose containing 0.01 M each of NaCl, KCl, and $CaCl_2$. The suspension was subsequently aerated and aliquots used as needed. Potassium ferricyanide (FeCN) was obtained from Fisher Scientific Co., Tris and Mes buffers were obtained from Sigma Chemical Co., sucrose from Mallinnckrodt. 2, 4-Dichlorophenoxyacetic acid (2, 4-D) was obtained from Nutritional Biochemicals Corporation. Fusicoccin was a gift of Professor Alessandro Ballio of Cittá Universitaria, Rome. An Aminco DW-2a spectrophotometer was used to measure FeCN reduction at 420 nm, using the dual beam mode with a reference at 500 nm. The FeCN concentration used was 0.4 mM. The sample was stirred continuously with a magnetic stirring assembly. A millimolar extinction coefficient of 1.0 was used for FeCN.

For the fusicoccin experiment cells were washed with growth medium without 2,4-D and placed in medium without 2,4-D for 8 hours, after which the growth medium was replaced by 0.1M sucrose. Cells in 0.1M sucrose with 0.02 M $CaCl_2$ and 0.05 M Tris-Mes, pH 7.0, were incubated with fusicoccin in the medium, added as an ethanolic solution, for 1 minute before FeCN addition. The percent effect after incubation with ethanol for 1 minute was substracted from the percent fusicoccin effect. The fusicoccin effects in Table I were obtained in the same way, except the cells were not incubated in medium without 2,4-D, but were washed twice with

TABLE I. *Fusicoccin Stimulation of Ferricyanide Reduction*

Fusicoccin (M)	10^{-9}	10^{-7}	10^{-5}	6×10^{-5}
Stimulation (%)	+ 0.4	+ 5.2	+ 37.7	+ 60.4

Cells were incubated 2.5 minutes with fusicoccin.
A rate was taken subsequent to FeCN addition.

"assay solution". Cells were incubated with fusicoccin for 2.5 minutes before FeCN addition.

2,4-D experiments were performed in "assay solution" with 0.013 M Tris-Mes buffer, pH 7.0. 2,4-D effects were obtained by measuring FeCN reduction over time and adding an aqueous solution of 2,4-D made up as the sodium salt, after the rate of FeCN reduction was observed to rise on aeration. The percent effect of 2,4-D was calculated from the maximum change observed after 2,4-D addition. In Table II 2,4-D was added in dimethylsulfoxide (DMSO) and the change on addition of DMSO to a second identical aliquot was subtracted from the 2,4-D effect. There was no large effect observed of the DMSO on FeCN reduction rate in the second control aliquot. The average value ± standard deviation is reported.

Results

Figure 1 shows fusicoccin stimulation of FeCN reduction by whole carrot cells after a 1 minute incubation, with two points for each concentration tested. The stimulation begins at about 10^{-7}M and maximum stimulation of about 20% at 10^{-4}M. The increase in stimulation with concentration appears to level off between 10^{-6}M and 10^{-4}M, as compared to 10^{-8}M to 10^{-6}M.

Table I shows fusicoccin stimulation of FeCN reduction after a 2.5 minute incubation. The stimulation again appears at about 10^{-7}M. The stimulation is higher throughout and does not saturate at the highest concentration, possibly a reflection of an effect from the high ethanol levels used for that concentration on metabolism or membrane permeability.

TABLE II. *2, 4-D Inhibition of Carrot Cell FeCN Reduction 2, 4-D Concentration 2×10^{-5}M*

Trial #	Effect (%)
1	- 14.9
2	- 13.6
3	- 25.5
4	- 32.5
5	- 16.9
	Average -20.7 ± 8.0

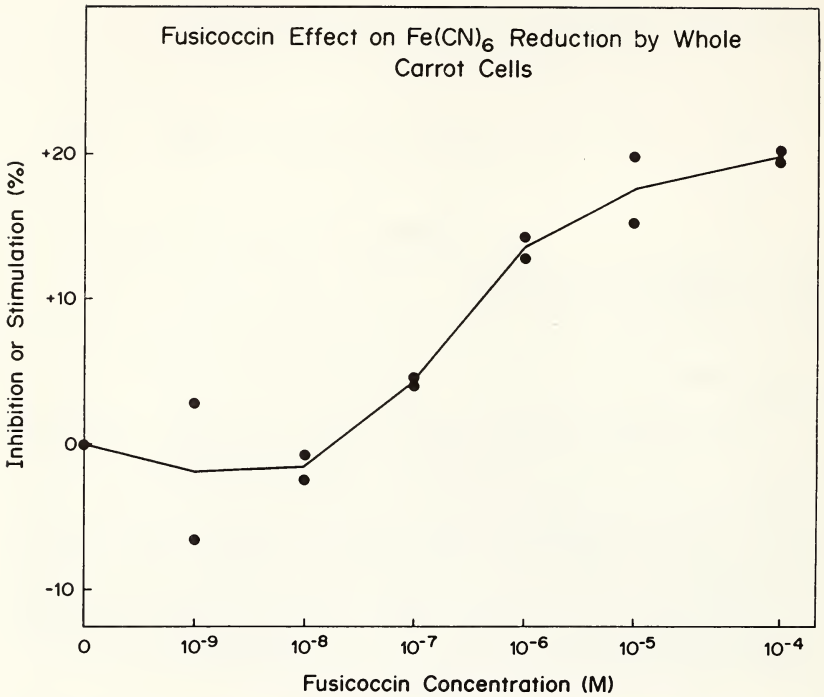

FIGURE 1 *Fusicoccin stimulation of ferricyanide reduction by carrot cells.*

Figure 2 shows the rise in FeCN reduction observed on aerating cells washed free of growth medium. 2,4-D at 1.8 x 10^{-5}M decreases this rate, beginning within a few minutes and continuing for an hour, when the rate of reduction is near the pre-rise level.

Table II is a summary of five of the types of experiments seen in Figure 2, using a 2,4-D concentration of 2 x 10^{-5}M, where the maximum inhibition ranges from 13.6 to 32.5 percent. The average is 20.7 percent inhibition.

Discussion and Conclusions

Results just presented indicate hormone control of plasma membrane electron transport in plant cells. Very little is known about how fusicoccin brings about its effects, but an electron transfer system in the plant plasma membrane could be one site of action in addition to a postulated stimulation of a plasma membrane H^+-ATPase. The stimulation of electron transfer by the toxin fusicoccin might exert important metabolic and control effects on the cell and be responsible for the changes in membrane potential and for the proton release that have been reported to be associated with fusicoccin. The redox system could interact with other plant hormones, or, if it is an NADH dehydrogenase, change the NADH/NAD^+ level in the cytosol.

The mammalian plasma membrane has a transmembrane NADH dehydrogenase (3). Results indicative of a transmembrane electron transfer system in plant cells have previously been presented (1) and this system shows the ratio of protons

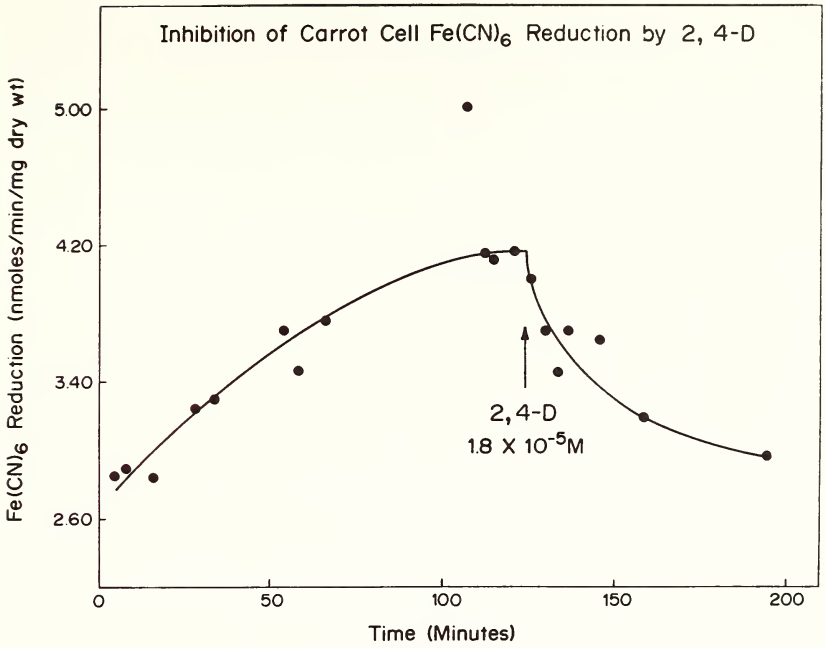

FIGURE 2 *2,4-D inhibition of whole cell ferricyanide reduction.*

released to FeCN reduced to be greater than one, which could hyperpolarize the cell membrane and suggests coupled proton transport, as in chloroplasts and mitochondria.

The 2,4-D inhibition observed in figure 2 and table II might be interpreted as the inhibition of an electron transfer system that is operating at a stimulated level. The stimulation could be due to the removal of 2,4-D from the cell, by outward diffusion from the cell as the cells are grown with 2,4-D at 2 x 10^{-6}M as the only growth regulator needed for growth in culture. The 2,4-D might inhibit the electron transfer system, allowing the cells to maintain a normal level of activity to oxygen, ferric iron or other acceptors. IAA (indoleacetic acid) also inhibits the rise in FeCN reduction rate.

We see opposite effects of fusicoccin and IAA for FeCN reduction by root tissue derived carrot cells and opposite effects have been seen by others on growth of corn root segments and lentile roots (5, 8). Here, in contrast to stimulatory effects seen by some on coleoptile and stem growth, fusicoccin stimulates and auxin inhibits FeCN reduction. Fusicoccin failed to stimulate growth in corn roots above 10^{-5}M, similar to Figure 1 of this study, where fusicoccin appears to approach a saturating concentration at 10^{-5}M.

In conclusion, the results demonstrate the control of plasma membrane electron transfer evidenced by fusicoccin stimulation and 2,4-D inhibition in carrot cells. Both auxins and fusicoccin are believed to have the plasma membrane as one of their sites of action. This system may be one means by which plant cells mediate their response to plant hormones and may explain in part the results observed with

fusicoccin. The basis of the responses of plants to hormones are poorly understood or unknown and there may be complex interactions of other hormones with this transmembrane electron transport system. This system may be one mode by which hormones bring about their interrelated action and varied effects, which include control of cell growth and development.

Acknowledgments

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Effects of Immunoactive and Cytotoxic Drugs on Cultured Rat Myeloma Cells.

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Introduction

The IR162 rat myeloma is a transplantable IgE-secreting tumor which was derived from a spontaneous tumor in a LOU/C rat (3). It has been established in cell culture as the Ta4 line (10, 11). Ta4 cells are tumorigenic in LOU/C and LOU/M rats, and they secrete IgE *in vitro*. The IgE produced by tumor cells is readily monitored in serum or in tissue culture fluid (11). The IR162 rat myeloma therefore provides a model system for assessment of putative therapeutic agents that might be of benefit in human myeloma. Compounds may be examined for inhibition or for stimulation of Ta4 growth, and for IgE synthesis *in vitro*. These compounds may then be evaluated *in vivo*.

Three classes of compounds have been chosen for evaluation *in vitro*. Cytotoxic agents were examined in Ta4 cells to determine whether they were lytic, and if there were a differential effect on cell growth and on secretion of a specific protein, IgE. There is ample evidence that the immune system can play a part in cancer therapy (5), and certain mouse plasmacytomas have been subjected to regulation by the immune system (1,20). Therefore a number of immunomodulating drugs were tested for their direct effect on Ta4 cells, which are of B lymphocyte origin (3). Finally, three compounds were examined which might help to elucidate the mechanisms of inhibition of Ta4 cells.

Materials and Methods

The Ta4 cells were propagated in stationary suspension cultures in RPMI 1640 medium supplemented with penicillin (100 units/ml), streptomycin (0.1 mg/ml), and 10 percent fetal calf serum. Passages were made twice weekly by pipetting to disperse cell clumps. The cells were diluted 1:10 in fresh medium. Late log phase cells were used in all experiments.

Cell growth was determined on the basis of the change in total cell protein using the Lowry protein assay as adapted for cell culture by Holden et al (17) or by cell counts using a Model ZBI Coulter counter. A total protein assay was initially chosen because of my interest in evaluating secreted protein. However, parallel determinations using total protein and cell counts gave similar results.

The IgE content in tissue culture media was determined by quantitative passive hemagglutination inhibition (HAI) (11). Briefly, anti-rat IgE antiserum (Miles Laboratories) was diluted serially in 96 well microtiter plates to which diluent or diluted cell culture medium was added. The plates were agitated and incubated at room temperature for 30 minutes. IgE-labelled sheep red blood cells were added; plates were agitated and incubated overnight; and the extent of hemagglutination inhibition was determined. All determinations were performed in triplicate.

Dose response curves were performed by adding compounds to triplicate samples of cell culture medium in which Ta4 cells were grown for 72 or 96 hours in order to establish tissue culture inhibitory dose 50's (ID50) for both cell growth and IgE synthesis. In order to calculate the ID50, growth or IgE content was plotted

versus the logarithm of the drug concentration, and linear regression was used on the linear portion of the curve. Since HAI titers depend on twofold serial dilutions, they are not as precise as protein determinations or cell counts. Therefore, cell growth and IgE synthesis were not considered to be differentially affected unless their respective ID50's exhibited more than a twofold difference. These experiments have been repeated with Ta4 cells in culture over a period of three years; and the cell line appears to be quite stable in its response to chemical agents.

The following agents were evaluated: cycloheximide (Sigma Chemical), theophylline (Sigma Chemical), aminophylline or $(theophylline)_2EDTA$ (Sigma Chemical), isoproterenol (K and K Laboratories), phytohemagglutinin M (Difco Laboratories), concanavalin A (Miles Laboratories), lipopolysaccharide (Difco Laboratories), pokeweed mitogen (Grand Island Biological), 5-bromo-2-deoxyuridine (Calbiochem), idoxuridine (Sigma Chemical), 8-azaguanine (Sigma Chemical), azathioprine (Burroughs Wellecome), estracyt (A.B. Leo, Halsingborg, Sweden), methotrexate (Sigma Chemical), cyclophosphamide (Mead Johnson), poly (I):poly (C) (Miles Laboratories), poly (A):poly (U) (Miles Laboratories), levamisole (Sigma Chemical), tilorone (Merrill-National Laboratories).

TABLE 1. *Drug Toxicity Levels*

Compound	Cell Growth ID50 (ug/ml)#	IgE Production ID50 (ug/ml)	Range (ug/ml)	Number of Experiments
Mitogens				
Phytochemagglutinin-M	>1/10*No effect	HAI Unreliable	1/10000-1/10	3
Concanavalin A	>50 No effect	HAI Unreliable	0.1-50	3
Endotoxin	>100 No effect	>100 No effect	0.1-100	2
Pokeweed Mitogen	>1/10*No effect	>1/10 No effect	1/10000-1/10	1
Base Analogs				
Bromodeoxyuridine	0.23	4.5	0.01-100	6
Idoxuridine	2.6	10	0.01-100	2
8-Azaguanine	16	ND	0.1-100	3
Azathioprine	53	100	0.1-100	2
Anticancer Agents				
Estracyt	36	22	0.1-50	1
Methotrexate	0.0029	ND	0.0005-50	3
Clclophosphamide	500	ND	0.1-500	1
Not activated	>500	ND	0.1-500	1
Activated	9	6	0.1-50	5
Immunostimulators				
PolyI:polyC	>100 No effect	>100 No effect	0.1-100	4
PolyA:polyU	>100 No effect	>100 No effect	0.1-100	4
Levamisole	340	240	0.1-1000	3
Tilorone	1.8	3.0	0.1-100	5
Others				
Cycloheximide	0.05	0.085	0.01-50	2
Theophylline	>100	>100	0.1-100	3
Isoproterenol	27	234	0.1-100	4

Data are expressed as the mean of determinations from several experiments.

* Since these compounds are not sold by weight, dilutions were used. Generally they are used at a 1/100 dilution for effective mitogenesis.

Results and Discussion

Comparisons of growth and IgE secretion yielded three patterns. Compounds such as the polynucleotides, mitogens, and theophylline, had no effect on either cell growth or IgE synthesis over the range tested. (Table 1). That range included those concentrations which were shown to be active in other systems. Most other compounds inhibited growth and IgE synthesis to approximately the same extent. At lower doses IgE synthesis and growth were equivalent for concanavalin A (Con A) and phytohemagglutinin M (PHA). At higher drug concentrations, HAI results were considered unreliable due to the agglutinating effects of these compounds.

Only the base analogs 5-bromo-2-deoxyuridine (BUDR) and 5-iodo-2-deoxyuridine (IUDR) produced a differential effect on cell growth and IgE secretion. Both drugs inhibited cell growth at significantly lower concentrations than IgE synthesis. The immunosuppressive purine analog azathioprine had a similar but less pronounced effect.

Cell lysis was occasionally observed at high drug concentrations but not at dosages at which the compounds are normally used. In confirmation of previous reports the release of IgE upon cell lysis was very small, and the IgE levels remained stable throughout the course of the experiments (10).

Since one of the goals of this work was to establish an *in vitro* model which would predict *in vivo* results, cycloheximide, theophylline, and isoproterenol were tested to characterize the system. Cycloheximide inhibits protein synthesis at the ribosomal level (7). It should therefore inhibit cell growth and IgE synthesis to approximately the same extent, and this was the case.

Two agents which increase cyclic adenosine monophosphate levels were tested because of the reports of the affects of cyclic nucleotides on immune cell function (15, 18, 24). Theophylline had no effect on Ta4 cells, either when it was used as theophylline or as aminophylline. Isoproterenol was equally toxic to growth and IgE synthesis.

The alkylating agent cyclophosphamide (CPA) is a phase nonspecific cytotoxic agent which is used in the chemotherapy of multiple myeloma (8). It has been shown to effectively reduce the tumor burden in rats bearing subcutaneous IR162 rat myelomas (10). CPA must be activated by the liver *in vivo* (8). The ID50 of CPA before activation was greater than 500 ug/ml. However, when rats were injected with 500, 200, and 100 mg/kg CPA and bled at one hour, at which time serum levels of the active metabolite are near maximum (30), the ID50 was 9 ug/ml and the dose response was essentially linear. Thus Ta4 cells respond similarly to human myeloma (8), and this assay may be used for serum drug levels. Methotrexate is a phase specific agent which acts as an antimetabolite and is commonly used for hematopoietic malignancies (23). Ta4 cells were sensitive to methotrexate, and therapy trials indicated the value of this agent *in vivo* against rat myeloma (Manuscript in preparation).

Cytoreductive therapy of multiple myeloma is generally only effective in reducing the tumor burden; spontaneous remissions are unknown; and patients are generally severely immunosuppressed (8). Human myeloma therefore appears to be a candidate for immunotherapy, and the rat model has potential for immunotherapy trials. Passive spleen cell transfer has been shown to prolong survival and has resulted in some cures (2), and Ta4 cells are sensitive to antibody and complement mediated lysis (unpublished). In certain mouse plasmacytomas the immunoglobulin acted as an important antigen in tumor rejection (13), and the extent of cell differentiation and immunoglobulin secretion was immunologically mediated.

Therefore, a number of compounds, which have been reported to have effects on cells of the immune system, were tested.

Neither the T-cell mitogens, PHA and Con A, nor the B-cell mitogens, pokeweed mitogen and endotoxin, had any effect on the tumor cells (14, 29). Mitogens were evaluated because of the lymphocyte origin of the Ta4 cells, although their state of differentiation is beyond that at which mitogens are generally active. Endotoxin was of particular interest because of its reported necrotic activity against tumors, which has been attributed to the production of tumor necrosis factor *in vivo* (16).

The double stranded polyribonucleotides have been reported to inhibit tumor growth in several rodent models (16, 19, 26). Neither was active against Ta4 cells. However, poly(I):poly(C) is a potent inteferon inducer in rodents (12), and the Ta4 cels show some sensitivity to rat interferon (unpublished). This agent may have some promise for immunotherapy. Tilorone (9, 21) and levamisole (6, 16, 25, 27) have been reported to be immunoactive and to be beneficial in certain cancers. Neither compound stimulated the growth of Ta4 cells; actually cell growth and IgE synthesis were equally inhibited by the drugs. Therefore, the polyribonucleotides, tilorone, and levamisole might be candidates for *in vivo* immunomodulation. They can be used in animals, but not at dosages which would reduce the tumor burden; and they do not directly stimulate the tumor cells.

BUDR and its related pyrimidine analog IUDR both inhibited the Ta4 cell growth at much lower concentrations than IgE synthesis. In fact at concentrations near the ID50 IgE synthesis proceeded at control levels (no drug added) for two or three days after cell growth ceased. These agents may have potential for sensitizing the tumor cells to immune killing. Certain metabolic inhibitors have been shown to alter the sensitivity of tumor cells to immune attack (28). These compounds also illustrate that the secretion of immunoglobulin by Ta4 cells is subject to modulation other than growth inhibition. Perhaps this is related to increased differentiation induced by BUDR in cultured neuroblastoma cells (4).

In conclusion the Ta4 cells have been used to evaluate several cancer chemotherapeutic agents and putative immunotherapeutic agents for their effects of growth and IgE synthesis. Most compounds produced equivalent effects on both parameters, but BUDR and IUDR inhibited growth while allowing continued IgE production. The assay has potential for screening putative chemotherapeutic agents for myeloma, and it can be used to assay serum levels of drugs to which the cells are sensitive.

Acknowledgments

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Metastatic Patterns in the Ta4 Transplantable Rat Myeloma

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Introduction

Multiple myeloma is a human neoplasm of relatively high incidence. Current therapy consists of cytotoxic agents, which normally reduce the tumor burden but do not result in cures (6). More studies are needed in myeloma therapy.

The IR162 rat myeloma is a potential therapeutic model for human multiple myeloma. The tumor was derived from a spontaneous ileocecal lymph node tumor in a LOU/C rat, and it was readily transplantable by subcutaneous or intraperitoneal routes into LOU/C and LOU/M rats, which are histocompatible (2, 3). The tumor cells have been reported free of oncogenic viruses (4), and this appears to reflect the human situation (12). IR162 cells secrete a monoclonal IgE. The tumor has been established in cell culture as the Ta4 line, which has remained tumorigenic and continued to secrete IgE *in vitro* (7, 9). In this report the metastatic properties of tumors initiated from the Ta4 line (Ta4 tumors) were studied.

Materials and Methods

The IR162 tumor was obtained from Dr. H. Bazin in Louvain, Belgium. The Ta4 line was developed at the University of Notre Dame Lobund Laboratory (7, 9).

Louvain/Wsl/M (LOU/M) rats were given Teklad L485 diet and tap water *ad libitum* (10). Subcutaneous tumors, initiated by the injection of cultured Ta4 cells, were minced, diluted in balanced salt solution, and one to three million viable cells were inoculated subcutaneously into young adult male rats between the ages of three and four months. Tumor growth was evaluated two to three times per week, and tumor size was calculated as the product of two perpendicular diameters.

Peripheral blood and bone marrow smears were stained with the Wright-Giemsa procedure (15).

Linear regression analysis and T test were performed using the Minitab program (14).

Results

Subcutaneous tumors initiated by the injection of first or second animal passage Ta4 cells (Ta4 tumors) were well vascularized. Serum from these rats contained large amounts of monoclonal IgE as detected by double gel diffusion or single radial immunodiffusion. In Table 1 data from 23 tumor bearers in four separate experiments are presented. Metastasis occurred primarily to ipsilateral axillary, inguinal, and retroperitoneal lymph nodes, as well as to parathymic lymph nodes. Splenomegaly was a consistent characteristic and was directly related to the weight of the primary tumor ($r = .9$). Tumor bearing rats were anemic, and the hematocrit was inversely related to the tumor burden ($r = .9$).

Following a lag period after inoculation, tumors became palpable, and tumor size increased linearly with time ($r = .9$). At autopsy tumor weight was highly related to calculated tumor size ($r = .7$).

Differential counts on femoral bone marrow smears were made on groups of rats at weekly intervals before tumors became palpable, and on rats with large

TABLE 1. *Pathology of Rats Bearing Transplanted TA4 Subcutaneous Tumors*

	Tumor-Free Controls[a]	Subcutaneous Tumor
Number of Observations	8	23
Tumor Weight (gm.)	0	21.7 ± 14.6
Spleen Weight (%)		
Body Weight	.17 ± .02	.23 ± .12
Hematocrit (%)	ND	37 ± 8
Peripheral White Cell Count (/m^3)	7147 ± 3962	8419 ± 2624
Incidence of Lymph Node Tumors		
Axillary	– – –	7/18
Inguinal	– – –	5/18
Lumbar or Renal	– – –	8/18
Mesneteric	– – –	0/18
Omental	– – –	0/18
Parathymic	– – –	11/18

a. Data are presented as the mean ± standard deviation.

tumors. Marrow metastasis was not detected in rats sacrificed before tumors became palpable. Injection of peripheral blood, spleen cells, and bone marrow cells from these experimental rats intraperitoneally into normal rats failed to produce tumors. Rats bearing large tumors had metastases in bone marrow, accompanied by a reduction in the erythrocytic, neutrophilic, and eosinophilic series (Table 2). Differential counts on peripheral blood revealed significant increases in lymphocytes (56% to 65%) although immature forms were not seen. Polymorphonuclear leucocytes were decreased from 40% to 30%. Red cell morphology was consistent with the presence of anemia.

TABLE 2. *Differential Results of Bone Marrow Smears*

Maturation Series (Percent)	Controls c	Tumor Bearing
Neutrophilic	[a]43.8 ± 3.6	34.5 ± 5.6[b]
Eosinophilic	5.1 ± 3.1	1.5 ± 2.1[b]
Basophilic	1.1 ± 1.2	1.4 ± 1.8
Erythrocytic	33.4 ± 2.9	25.5 ± 4.7[b]
Lymphocytic	12.8 ± 2.9	13.0 ± 1.9
Mature Plasma Cells	0.7 ± 0.5	1.0 ± 0.9
Megakaryocytes	1.8 ± 1.0	2.0 ± 1.2
Imature Plasma Cells or or Tumor Cells	0	20.3 ± 2.7
Tumor Weight (gm.)	0	32.4 ± 10.8

a. Data are presented as the mean ± standard deviation
b. Significant difference at the 0.5 level by the two sample T test
c. There were 10 rats in each group

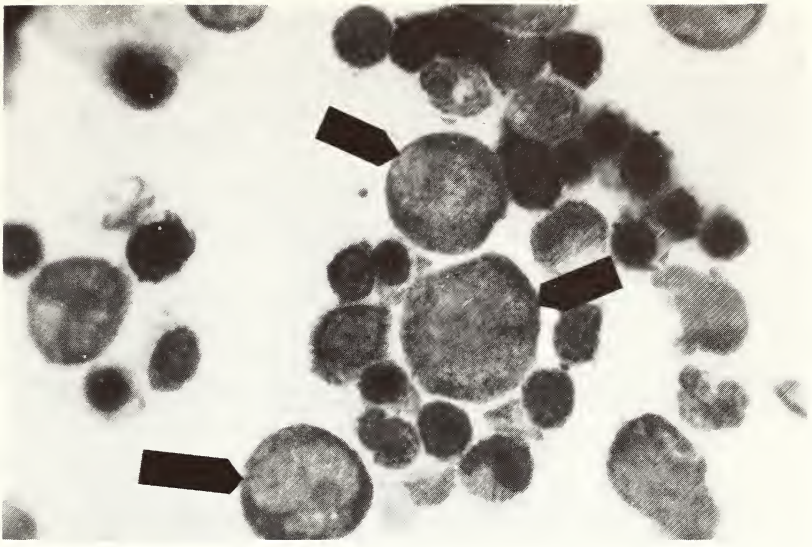

FIGURE 1. *Ta4 Tumor Metastasis in Bone Marrow*

Tumor cells had large nuclei, prominent golgi apparatus, and would be classified as immature plasma cells, plasmacytoid cells, or plasmablasts (Figure 1).

Discussion

The Ta4 cells in culture and Ta4 tumor present a useful model for the therapy of human multiple myeloma. The Ta4 cell line has been useful in screening putative cytoreductive and immunomodulatory agents (8). We wished to characterize the *in vivo* properties of the Ta4 tumor and evaluate it as a model for multiple myeloma.

Both the rat Ta4 and human myeloma are plasma cell tumors, and both secrete immunoglobulins. Because of the very low levels of IgE in normal rats (5), it is easy to detect the monoclonal IgE in serum of tumor bearing rats.

A multiple myeloma model should be highly metastatic, and the subcutaneous Ta4 tumor metastasizes readily to draining lymph nodes. However, the probable site of origin and predominant site of growth in multiple myeloma is the bone marrow (12). The transplanted Ta4 cells did infiltrate the bone marrow, but this was a late event in the course of the tumor. Anemia is a distinguishing characteristic in both the rat and human diseases (6, 12), as is the related reduction in cells of the erythrocytic series in the bone marrow. The splenomeagaly also appeared to reflect metastasis. The enlarged spleens in tumor bearing rats were previously reported to have abnormal cellular architecture and to contain large numbers of tumor cells (7).

A subcutaneous inoculation route was chosen for two reasons. 1) Since chemotherapeutic agents are often administered intraperitoneally to rodents, we wished to separate the sites of primary tumor growth and drug presentation. 2) Subcutaneous inoculation allowed the evaluation of tumor development by measurement of external size. When therapy is administered and then discontinued, the length of the lag before tumor appearance may reflect the extent to

which the tumor cells were killed. This is a reasonable assumption since tumor growth was linear with time after the tumor became palpable and therapy trials with methotrexate indicated that it was probably the case (Manuscript in preparation). Serum IgE levels may also be used to periodically monitor tumor burden although this would not be the method of choice because bleeding causes additional stress to the rats.

Current therapy of multiple myeloma generally reduces the tumor burden, but it does not result in cures (6). The disease is itself immunosuppressive, as are the chemotherapeutic agents (6, 11, 12, 13). We were therefore particularly interested in a model which could be used to evaluate putative immunotherapies, which would be useful after the tumor burden was reduced. Therefore, we chose an inoculum which resulted in a low tumor burden and a relatively long lag before tumors became palpable. During that period of low tumor burden, potential immunotherapies could be tested. The Ta4 cells are susceptible to antibody-complement mediated cell lysis *in vitro* (unpublished), and they appear to be sensitive to immunotherapy *in vivo* (1). In conclusion the Ta4 cell line and Ta4 tumor appear to provide a usable model for studying both cytotoxic and immunomodulatory therapies for human myeloma.

Acknowledgments

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Chromosome Banding of *Cercopithecus neglectus*

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Introduction

Chromosome analysis will aid in understanding the phylogenetic relationships of the Cercopithecoidae. Within the genus *Cercopithecus*, the chromosome number varies from 48 to 72 (2), indicative of numerous chromosomal rearrangements that have occurred during evolution. Consequently, karyotypic studies are needed to provide information on the chromosome number, morphology and banding pattern for these species. Previous efforts to study the chromosomes of *Cercopithecus neglectus* conducted in the pre-banding era have led to conflicting chromosome counts (1, 8). Only recently has this species been reinvestigated by Dutrillaux et al. (4) who reported an R-banded karyotype. Q-banding is a fluorescent method which stains positively in the areas that respond negatively by R-banding. Therefore, Q-banding is complementary to R-banding and provides unique information about the Q-positive regions. Q-banding has not been reported for *C. neglectus* nor for most of the other 25-30 species in the superfamily Cercopithecoidae. Those few species that have been published include *Miopithecus talapoin*, *Cercopithecus aethiops* (3), and *Erythrocebus patas* (7).

Methods

Peripheral blood was obtained from four males maintained by the Psychology Department at Indiana University, Bloomington. Four lymphocyte cultures were prepared for each specimen using 10ml of Chromosome Medium 1A (GIBCO). Cultures were incubated at 37°C for 72 hours. During the last 90 minutes of incubation, the cells were exposed to .001mg of Colcemid (GIBCO) to arrest the cells at metaphase. This was followed by treatment with hypotonic solution (.075M KCl) for 10 minutes and then fixation using three changes of methanol: acetic acid (3:1). Slides were prepared, stained in 4% Giemsa (Harleco) and scanned for chromosome spreads. Photos were taken at 1200X on 35mm Kodak Technical Pan film. Slides were destained then stained with 0.5mg/ml quinacrine mustard dihydrochloride (Sigma) in McIvaine's buffer (pH 6.5) for 20 minutes. Following a 10 minute wash in distilled water, slides were mounted in buffer and observed under epifluorescent illumination with an Olympus Vanox microscope. Photographs were taken using Kodak Tri-X film.

Results and Discussion

Tappen (8) reports a diploid number of 60 for *C. neglectus* based on one male specimen. Efforts by Chiarelli (1) to karyotype the species resulted in different conclusions from each of two specimens. He observed a diploid number of 58 and 62 and noted differences in the chromosome morphology as well. More recently Dutrillaux et al. (4) proposed an R-banded karyotype with $2n = 62$, although the number of specimens they used is not clearly specified. The authors claim that their analyses utilized either one or two animals for each species reported. Using four unrelated male specimens, we report a diploid number of 62 in each. Previous studies which failed to find 62 chromosomes may have been caused by incorrect species identification, chromosomal rearrangements unique to that specimen, or previously unrecognized subspecies. Since *C. neglectus* is distinctively identifiable by the white beard and orange crest on the forehead, thereby minimizing the likeli-

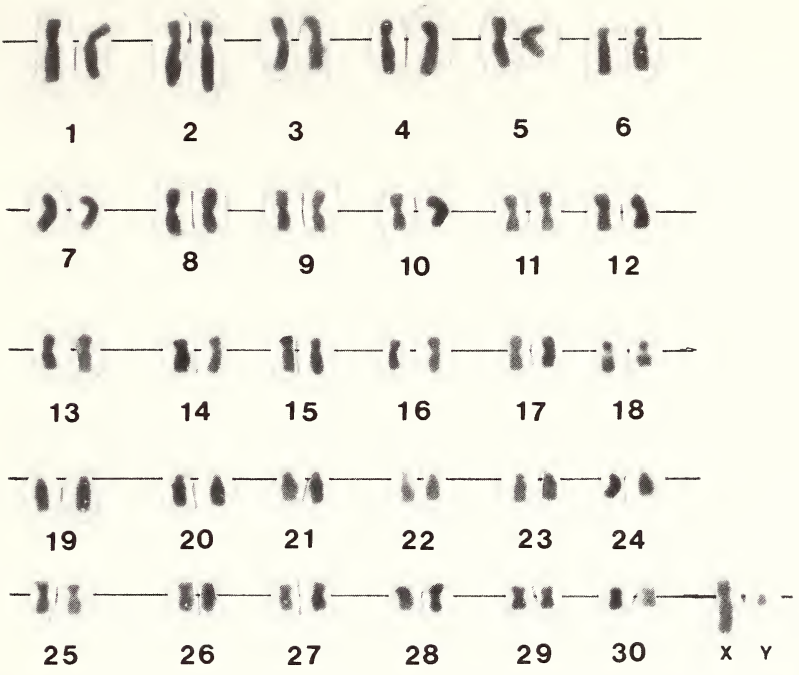

FIGURE 1. *Giemsa stained karyotype of Cercopithecus neglectus.*

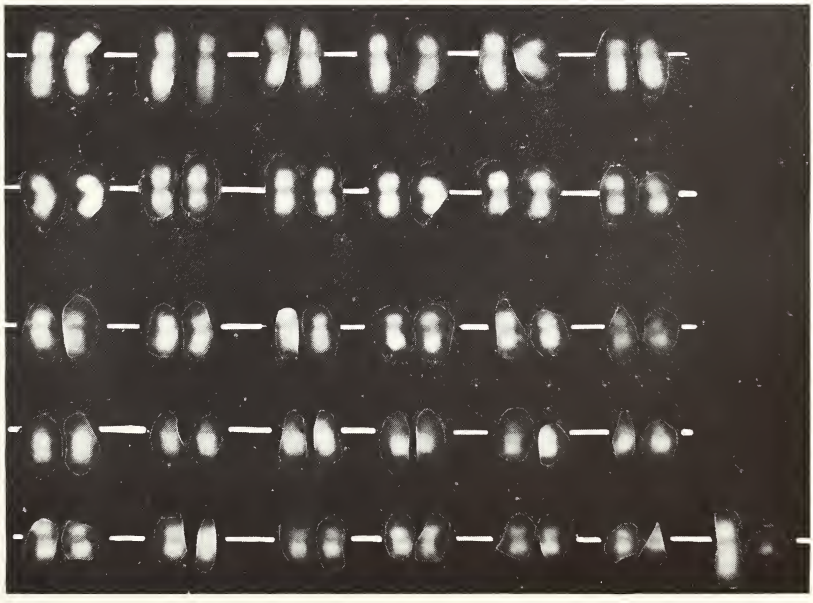

FIGURE 2. *Q-banded karyotype of the same chromosome spread shown in Figure 1.*

hood of missidentification, confirmation of the species integrity is aided by chromosome reports from diverse sources.

The relative size and centromeric position are most readily defined on Giemsa stained preparations (Figure 1). The karyotype consists of seven large submetacentrics [1-7], five medium metacentrics (7-12], eleven medium and small submetacentrics [13-17, 25-30], seven acrocentrics [18-24] and the sex chromosomes.

Giemsa staining delineates the chromosome morphology, but does not enable complete chromosome identification. Therefore, sequential staining was used to yield a Q-banded karyotype (Figure 2). Positive bands are located in the AT rich regions of the chromosome and can display region to region variability of intensity. The X chromosome is comparable in size, centromeric position, and staining pattern to the X chromosome of other primates. However, the fluorescent pattern of the Y chromosome has not been reported for this genus. The small short arm is nonfluorescent and there is a broad band of medium intensity located medially in the long arm.

The marker chromosome 18 is most distinctive due to the unstained secondary constriction observed when Giemsa stained and is found in all members of the genus studied. In several other genera of old world monkeys Henderson et al. (6) demonstrated that this corresponds to the rDNA genes and represents the nucleolar organizing region (NOR). Positive silver staining in *C. aethiops* by Estop et al. (5) implicates this as the NOR for all Cercopithecoides. Among six specimens observed by Estop and coworkers, one marker chromosome lacked a secondary constriction and two others revealed size related heteromorphic variation. The four unrelated specimens observed in the present study did not display size heteromorphisms.

The NOR regions of human chromosomes are located on the short arm of the D and G group acrocentrics and are often positioned close together, a phenomenon known as association. Among 44 *C. neglectus* spreads sampled from the four males, 14 (32%) were laterally associated such that the NOR were in contact and 9 (20%) located within two chromosome lengths of each other. Investigation of human chromosomes by Warburton et al. (9) demonstrated that the number of rDNA gene copies in a chromosome is positively correlated with the frequency of satellite association. Since strong association is also demonstrated in *Cercopithecus*, it would be of interest to test this observation with heteromorphic chromosomes from old world monkeys as well.

Acknowledgments

We wish to thank Dr. Michael Peterson and Rusty Schmidt of the Psychology Department, Indiana University, Bloomington for providing the blood samples. Their time and cooperation are greatly appreciated.

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Effects of Submersion, pH, Time, and Certain Inhibitors on Maize and Rice Root Respiration

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Introduction

This study is a continuation of experiments on the respiration of cereal root-tip segments (2). In the previous study marked contrasts were found between the respiratory responses of maize and rice to increases in external oxygen concentrations with the maize roots exhibiting the greater stimulation in both oxygen input and carbon-dioxide output. Factors in the present study include submersion, pH, time, and certain chemical treatments. This study further compares maize and rice root-tip respiration responding to inhibitors which have been shown to influence respiratory pathways (3).

Materials and Methods

One-centimeter root-tip segments of maize (Zea mays) were supplemented by similar segments of rice (Oryza sativa) roots. Oxygen input and carbon-dioxide output were measured by standard methods with Warburg manometers (6). Gas-exchange rates were determined for previously soaked root segments transferred to moist filter paper in Warburg flasks. Differential treatments included concurrently submerged segments, contrasted pH, duration of exposure, and the addition of various test reagents. All rate measurements were made at 25° C and expressed as "Q" values (μl/hr x mg dry wt.).

Results and Discussion

Effect of Submersion

The rate of oxygen input by root-tip segments directly exposed to moist air was 20% higher than with those submerged. This was true for both the maize and rice roots (Figure 1). This relates to the limited solubility of oxygen in warm aqueous solutions (6) restricting the rate of oxygen supply to the submerged roots. Also, the rate of oxygen input by the rice roots was 40% higher than by the maize. This is believed to be related to the finer, more filamentous texture of the rice roots which permitted more rapid penetration of oxygen to the respiratory centers.

Effect of pH and Time

Oxygen-input rates of the control root tips were essentially equal at pHs 4.4, 6.5, and 9.3 during hour-1 (Figure 2). The range of QO_2 values was from 5.9 to 6.1. However, hour-4 measurements of the controls indicated a decrease in rate with the higher pHs so that the measured rate of oxygen input at pH 9.3 was only 75% of that at pH 4.4, and the rate at near neutrality was intermediate. In addition, it should be noted that the oxygen-input rates of the controls at hour-4 were substantially lower at all pHs then during hour-1 owing to a depletion of limited respirable substrate in the excised root-tip segments.

Effect of Cyanide

Figure 2 also shows a marked inhibition in oxygen input in hour-1 by preim-

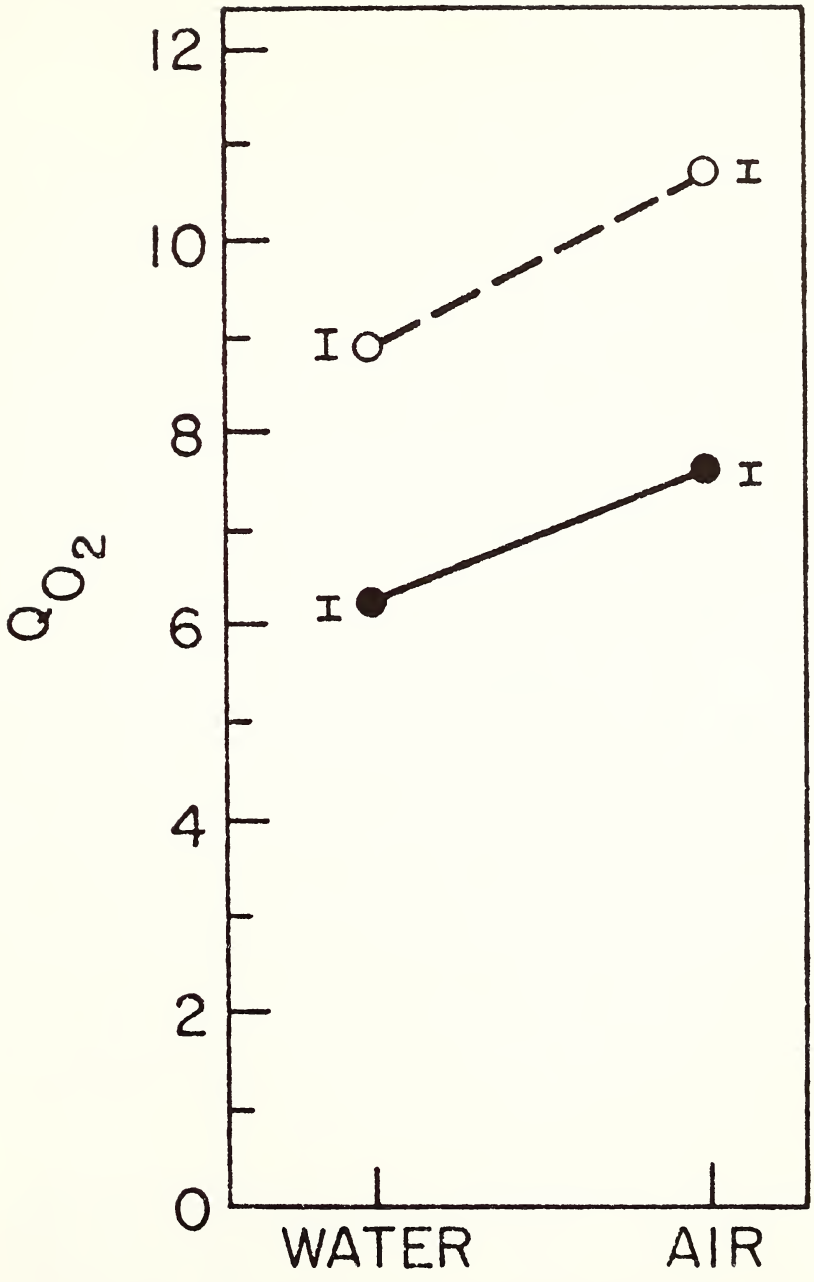

FIGURE 1. *O_2-input rates in water and in air, ○— — rice, ●— — maize; bars represent standard errors of triplicates.*

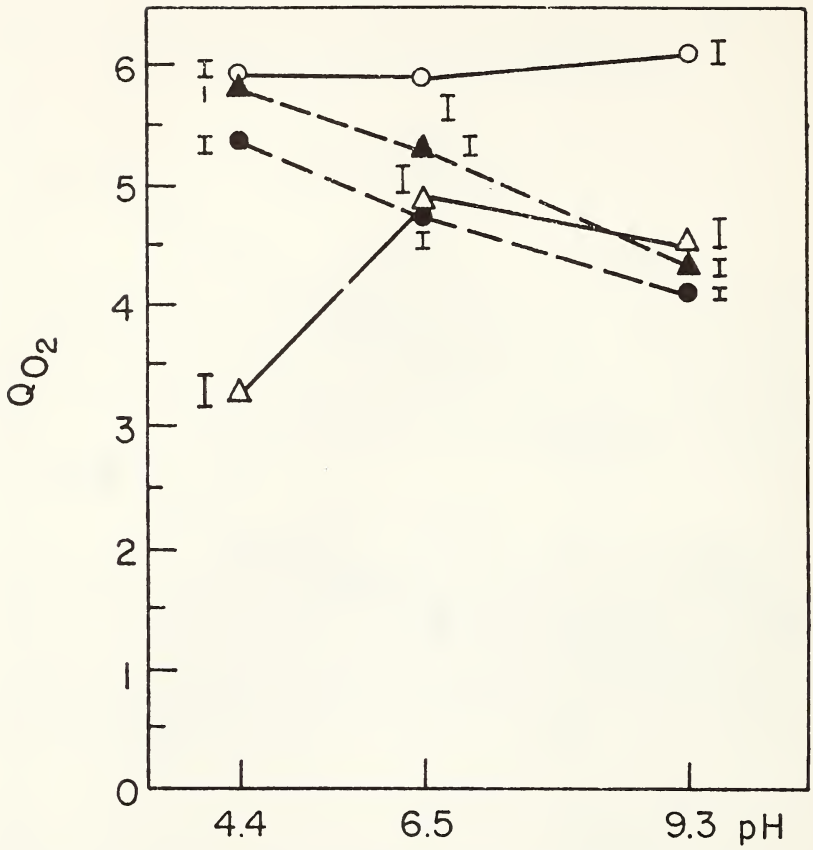

FIGURE 2. *O_2-input rates by maize root-tip segments influenced by pH, time, and-cyanide.* ○— — *controls, hour-1;* ●— — *controls, hour-4;* △— —cyanide treated, hour-1; ▲— —cyanide treated, hour-4.

mersion of the root-tip segments in buffered 1 x 10^{-3} M KCN solution. This inhibition was roughly 50% and occurred at pH 4.4. On the other hand, hour-4 oxygen input exhibited recovery at pH 4.4 and some stimulation at all pHs. This loss of inhibition is attributed to volatilization of the cyanide. Cyanide inhibition of respiration is ascribed to a blocking of the respiratory oxidation chain involving cytochromes (1, 3).

Dipyridyl Effects

The responses in air of maize and rice root-tip segments to pretreatment with 1 x 10^{-3} M dipyridyl at pH 4.4 are shown in Figure 3. Dipyridyl strongly inhibited the input of oxygen reducing it to approximately 50% of the control rate. This was true for both the maize and rice root-tip segments and is attributed to blockage of aconitase which converts citric acid to isocitric acid in the citric-acid cycle (3). As with oxygen input, carbon-dioxide output was also inhibited by dipyridyl. Here the maize roots exhibited an inhibition of 40%, the rice 30%. These lower values compared with the effect on oxygen input indicate less carbon dioxide-output inhibition

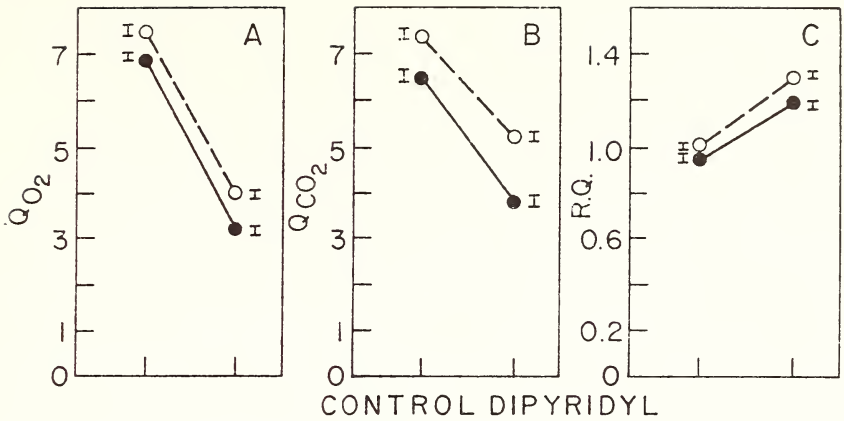

FIGURE 3. *Dipyridyl effects on root-tip segment gas exchanges.* ○— — *rice,* ●— — *maize. A, O_2 input; B, CO_2 output; C, respiratory quotient (R.Q.).*

owing, in part, to anaerobic carbon-dioxide production. The lower inhibition with the rice roots is considered to be due to a greater capacity for fermentation activity.

In consequence of less inhibition of carbon-dioxide output than oxygen input, RQ values were increased. With maize the average controls RQ of 0.95 was increased to 1,2, and increase of 25%. Similarly, rice root tips exhibited an increase from 1.0 to 1.3.

Dipyridyl plus Dieca

In experiments with 5 x 10^{-4} M dieca (diethyldithiocarbamate) it was necessary to renew the dieca treatments every 15 minutes because of its rapid decomposition (4). With the maize-root segments the dieca treatment over a 90 minute period depressed oxygen input 11% (Figure 4), in contrast to dipyridyl's 50%. When the dieca treatment was combined with dipyridyl, the oxygen input was depressed 34%. This, compared with dipyridyl alone, gave 16% less depression in oxygen-input rate.

Somewhat similar relationships by the rice-root segments were evident. Treatment with dieca alone gave an inhibition of 27% compared with the 11% for maize. However, when the dipyridyl and dieca were combined in a single treatment, oxygen input was depressed 10% less than with dipyridyl alone. Thus with both maize and rice, the addition of dieca alleviated the inhibitive action of the dipyridyl. This suggests competition in the penetration and action by the two inhibitors. Also, the greater response by rice than by maize to these inhibitors is thought to be related to the finer texture of the slender rice roots facilitating easier penetration and action. Incidentally, the work of James and Ward (5) with barley and wheat roots showed a species contrast for the dieca-induced inhibition with the barley roots the more sensitive. The difference was thought due to different levels of ascorbic-oxidase activity.

Dipyridyl plus Citrate

Maize root-tip segments pretreated with 1 x 10^{-3} M dipyridyl again showed marked depression in oxygen input. The addition of 3.3 x 10^{-2} M sodium citrate, however, decreased the dipyridyl inhibition of oxygen input 10%. This decrease is

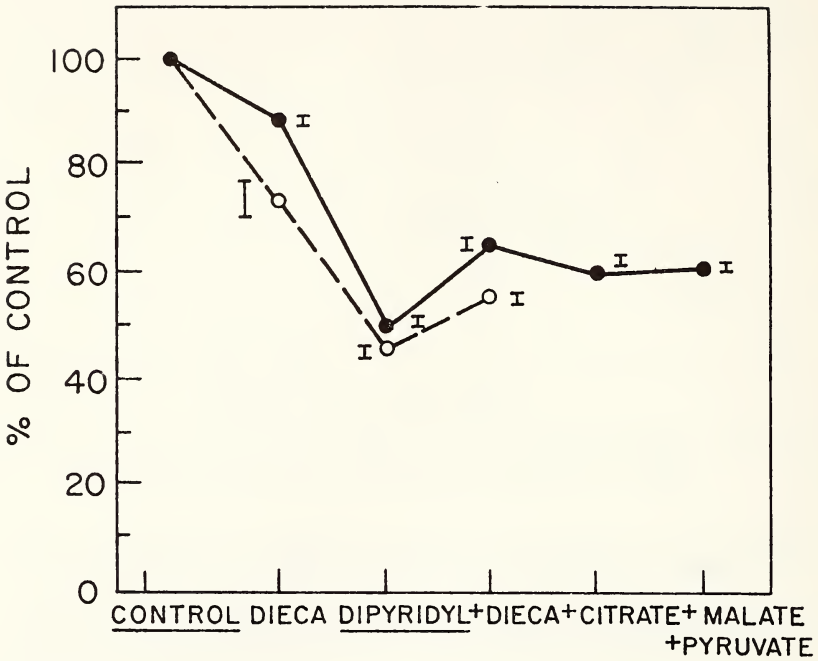

FIGURE 4. *Effects of dieca, dipyridyl, dipyridyl plus dieca, dipyridyl plus citrate, and dipyridyl plus malate and pyruvate.* ○— — *rice,* ●— — *maize.*

ascribed to a promotion of the citric-acid cycle by partially reversing the dipyridyl inhibition at the citric-acid to isocitric stage (3).

Dipyridyl plus Sodium Pyruvate and Malic Acid

The addition of 3.3 x 10^{-2} M sodium pyruvate and 3.3 x 10^{-2} M malic acid to dipyridyl-treated maize root tips decreased the dipyridyl inhibition of oxygen input 11%. This is equivalent to a 22% increase in oxygen input calculated on the basis of the dipyridyl-inhibited rate. This effect may be attributed to a promotion of the acetyl-CoA and succinyl-CoA steps in the respiratory chain (3).

Conclusions

Factors such as submersion and cyanide, during the first hour of exposure, acted to restrict oxygen input owing to the relatively low solubility of oxygen in water, and to interference of the respiratory oxidation chain in the case of cyanide. Dipyridyl, an iron chelating agent, greatly reduced both oxygen input and carbon-dioxide output. Since the decrease was more marked with the oxygen input than with the carbon-dioxide output, an increase resulted in the RQ. All of these effects took place in both species. Dieca, a copper-reacting agent, was found to be less inhibitory, either alone or when combined with dipyridyl, indicating competition between the two inhibitors. A similar effect was observed with citrate and with pyruvate plus malate.

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Figures for "Effects of Submersion, pH, Time, and Certain Inhibitors on Maize and Rice Root Respiration" by Raymond E. Girton.

Q_{O_2} and Q_{CO_2} are rate values as ul gas per hour and per mg dry weight. R.Q. values are CO_2/O_2 ratios.

CHEMISTRY

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ABSTRACTS

Computer-Assisted Nitrate Analysis System Using a Nitrate Ion Selective Electrode and an Apple II Plus Microcomputer. Stanley, L. Burden, Douglas W. Taylor, Christopher L. Myer and Mark A. Nussbaum, Department of Chemistry, Taylor University, Upland, Indiana 46989.——Software has been developed and hardware configured to enable an Apple II Plus microcomputer to control the acquisition, reduction and display of data from a nitrate ion selective electrode. The computer samples potential readings from the electrode, determines when electrode-solution equilibrium is reached, and stores the equilibrium potential reading. Measurements from standard solutions are plotted in color on a television set using high resolution color graphics to display a calibration curve. A cubic fit to the standards is made and also displayed in a different color passing through the calibration points. The cubic fit allows measurements to be conveniently made in the lower concentration (.1-2ppm) non-linear region of the calibration curve as well as on the linear region. Potential readings from unknowns are acquired in a similar fashion, the cubic equation is solved by the Newton-Raphson iterative method and the concentration is printed on the television. Hard copy output of all data, calibration curve plot, fitted equation, and unknown concentrations is available using a Paper Tiger 460 printer. The precision and accuracy of the system is equal to manually acquired and plotted data but the time required for the analysis is significantly decreased.

The Occurrence of Certain Toxic Organics in the Nature and Their Degradation. Robert H. L. Howe, and Roberta C. Howe, West Lafayette, Indiana 47906.——The occurrence of phenols, pyridines, and cyanides in the nature, unrelated to industrial processes, is discussed. Their degradation by natural processes is presented.

The Hydrolysis of Bovine Insulin A-chain by Guanidine-stable Chymoelastase in the Presence of Denaturant. Katherine J. Jordan and Eric R. Johnson, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——Guanidine-stable chymoelastase, a denaturant-stable protease isolated from Pronase, was found to catalyze the hydrolysis of bovine insulin A-chain (glycyl chain) in the presence and absence of 6.0 *M* guanidinium chloride. In the presence of this denaturant, an average of two peptide bonds per insulin A-chain molecule was hydrolyzed by the stable protease. However, only one peptide bond per insulin A-chain molecule, on the average, was cleaved by this enzyme in the absence of guanidinium chloride. The appearance of an additonal cleavage site on the insulin A-chain molecules in the presence of denaturant indicates that the guanidinium chloride unfolds the peptide substrate, rendering internal cleavage sites accessible to the stable protease. Thus guanidine-stable chymoelastase can be used in con-

junction with the denaturing properties of guanidinium chloride for the cleavage of proteolysis-resistant polypeptides and proteins.

Phosphorus Ligand Size Effects Upon Reactions with $W(CO)_4$ (pyridine)$_2$. CONSTANCE A. KIESLER and JOHN A. MOSBO, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——The steric effects of phosphorous ligands (L and L′) upon the *cis-trans* distributions of $W(CO)_4LL'$ products were studied for the reactions of $W(CO)_4$ (pyridine)$_2$ with L and L′. When L = L′, the sterically dissimilar ligands methyl (diphenyl)-, ethyl(diphenyl)-, isopropyl (diphenyl)-, and tert-butyl (diphenyl)- phosphine were chosen because of their comparable electronic properties. Through integration of 31-phosphorus NMR spectra, it was observed that an increase in ligand size brought about a decrease in *cis*: *trans* product ratio. Also investigated were the reactions of L′ with $W(CO)_4$ (PPh_2Et) (pyridine) which provided $W(CO)_4$ (PPh_2Et) L′ products. The resulting *cis*: *trans* ratios were discussed in terms of proposed reaction mechanisms and ligand sizes as defined by cone angles.

Asymptotic Expansions of the Eigenvalues of Burrau Molecules. PAUL C. MCKINNEY, Department of Chemistry, Wabash College, Crawfordsville, Indiana 47933.——Two nuclei and an electron bind together to form a Burrau molecule. The Schrodinger equation for these simple molecules has the advantage that it can be separated into three ordinary differential equations. One of the equations can be solved with elementary functions and it generates the quantum number for the z-component of the angular momentum, m. The two remaining equations, which have the same general form,

$$\frac{d}{dx}\left[(1-X^2)\frac{dP(x)}{dx}\right] + \left[\frac{-m^2}{(1-X^2)} + 2abx - a^2(1-X^2) + t\right]P(x) = 0,$$

where a and b are molecular parameters, t is the eigenvalue, and m is an integer, may be investigated with infinite power or functional series. Unfortunatley, these series are divergent in general, but they do provide asymptotic descriptions of the eigenvalues and eigenfunctions. It is possible to determine asymptotic expansions for t when the molecular parameters, a and b, both small, or one is small and the other is large, or when both are large. The results of these expansions are presented as an aid for numerical calculation of the eigenvalues.

The Synthesis of β-lactams Using a Photochemical Reaction. LAURA L. NELSON and LYNN R. SOUSA, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——Recently we discovered a photochemical reaction of 1, 1-dioxo-2-aryl-4-thiazolidinones that produces 2-azetidinones in reasonably good yield. 2-Azetidinone rings (β-lactams) are a crucial element in the structures of β-lactam antibiotics such as penicillin and cephalosporin. With this in mind we set out to use this photochemical β-lactam synthesis to make a simple compound with potential antibiotic activity: 1-acetic acid-4-furyl-3-(methoxycarbonylhydroxymethyl)-2-azetidinone.

The sequence of synthetic steps begins with a one-pot reaction to produce 2-furyl-4-thiazolidinone from thioglycolic acid, ammonium carbonate, and furfural. The nitrogen was then alkylated with the requisite functional group (methyl choroacetate was used). The next step, oxidation to 1,1-dioxo-2-furyl-3-(methylacetate)-4-thiazolidinone, proved difficult. Finally, a procedure using $KMnO_4$ produced the desired product. Problems in separation and analysis will be discussed. Condensation of the active methylene with methyl pyruvate will yield the thiazolidinone

with the proper functionality targeted for biological activity. Work on the final photochemical SO_2 expulsion to produce the desired β-lactam will also be discussed.

The ^{18}O-Isotope Effect in NMR Spectroscopy: A Method for Simultaneously Following Kinetics and Establishing the Site of Bond Cleavage During the Hydrolysis of Phosphate Monoesters. JEAN E. PARENTE, JOHN M. RISLEY and ROBERT L. VAN ETTEN, Department of Chemistry, Purdue University, West Lafayette, Indiana 47907.——An upfield shift in the ^{13}C-NMR signals of various organic compounds upon replacement of ^{16}O by ^{18}O has been shown to occur in ^{13}C-NMR spectroscopy [Risley, J. M. and Van Etten, R. L. (1979) *J. Amer. Chem. Soc.* 101, 252-253]. A similar observation of an upfield shift has been described for the ^{31}P-NMR signal of inorganic phosphate [Cohn, M. and Hu, A. (1978) *Proc. Natl. Acad. Sci. USA 75*, 200-203]. These ^{18}O-isotope effects have great utility in studies of reaction mechanisms. The ability to measure the isotopic content of substrates and products, simultaneously, as a function of time, provides distinct advantages over previously-used discontinuous methods of analysis such as mass spectroscopy, where the compound(s) of interest often require isolation and derivatization before analysis. In particular, the NMR techniques are very useful for studying enzymatic (and non-enzymatic) reactions of phosphate esters. We have examined the hydrolysis of [α-^{13}C, ^{18}O] benzyl phosphate catalyzed by homogeneous human prostatic acid phosphatase, making use of the ^{18}O-isotope effect in ^{13}C-NMR. It is demonstrated that the application of the ^{18}O-isotope effect in NMR spectroscopy affords a convenient, non-destructive method of analysis for following kinetics and for determining the position of bond cleavage during such enzyme-catalyzed hydrolysis reactions.

An Improved Qualitative Test for Acetate Ion. ROBERT E. VAN ATTA, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——Qualitative tests for acetate ion rarely appear in general chemistry laboratory assignments, owing to the unreliable nature of existing tests for the ion. A modified version of the basic ferric acetate test has been developed which has yielded an average accuracy of about 90% in the hands of inexperienced analysts. The test involves the formation of the characteristic brown basic ferric acetate when the warm unknown solution, previously treated to remove interfering cations and anions, is added to concentrated ferric nitrate reagent and the color produced compared with that obtained with a similarly treated blank test solution. Certain cations, sulfide, iodide, and some oxygenated anions interfere; simple procedures for preliminary removal of these interfering ions are also described.

Apple Computer Simulations Used in Teaching Chemical Instrumentation. JOHN F. ZIMMERMAN, Department of Chemistry, Wabash College, Crawfordsville, Indiana 47933.——The advent of "low cost" personal computer systems with graphics capability makes it possible, via simulation, to bring "real" instrumentation into the classroom. Computer simulations provide the ability to generate controlled presentations of time-dependent phenomena. This capability has been combined with computer text, color graphics and sound to produce lecture demonstrations in two areas, chromatography and the interaction of electromagnetic radiation and matter.

Investigation of Some Hydroxamic Acids by Thermometric Titrimetry

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Introduction

Hydroxamic acids, generally RCON(OH)R′, are interesting and versatile compounds which have quite a distinguished history of involvement in chemical reactions. H. Lossen (11), in 1869, reported that the reaction between diethyl oxalate and hydroxylamine yielded an acidic compound which he named oxalohydroxamic acid. The reaction discovered by Lossen has since been found to be quite general and forms the basis for a qualitative test for esters (12).

The acids are found also in nature and are known to have interesting biological properties (16); indeed, they are by-products of a number of biochemical reactions (2). The qualitative test for esters is based upon formation of hydroxamic acids and their complexing properties with iron (III) (12). It has been conjectured that they could play an important role in biochemical processes involving transport of trace metals throughout living systems. Indeed, their complexing action is not limited to iron (III) but encompasses many other metals: cobalt, copper, zinc to name only three (14). Hydroxamic acids also occur as the radiolytic degradation products of solvents and diluents used in the extraction processes for the recovery of uranium and plutonium from irradiated fuels (1, 13).

It is essential that these somewhat obscure but clearly important compounds be determined accurately in a variety of matrices, and, although a number of methods do exist (3), it was considered to be appropriate to investigate them through the use of thermometric titrimetry (8-10). This method is not only a sensitive analytical technique but also has the potential of producing data of fundamental imortance: enthalpies, Gibbs free energy, entropies and equilibrium constants (5). It is the object of this paper to report on such studies undertaken with these compounds.

Method and Apparatus

Thermometric titrimetry is a simple technique relying upon a universal property of all chemical reactions for endpoint detection: the evolution or absorption of heat. Generally, during the reaction, heat is absorbed or evolved and when this process ceases the end of the reaction is signaled, the latter may be detected using a simple thermistor circuit. The complete apparatus is shown in Figure 1, and consists of a small Dewar vessel of about 15 ml. capacity fitted with a cover suitably bored for a mechanical stirrer, a resistive heater, a thermistor heat sensor and a reagent delivery tube. The thermistor forms one arm of a Wheatstones' bridge circuit the output of which is connected to an amplifier and chart recorder. The titrant is delivered through a small diameter Teflon tube connected to a syringe driven by a synchronous motor. The Dewar vessel is usually immersed in a waterbath thermostated at 25°C. so that the experiments may be conducted at a constant known temperature. More details concerning available apparatus and reaction conditions are given in reference (5).

The method used for the investigation was akin to a conventional titration except that the titrant was added continuously at a constant rate, and the temperature of the stirred solution was monitored continuously by the thermistor circuit. Figure 2 shows the type of data normally produced by titration of a weak the curve

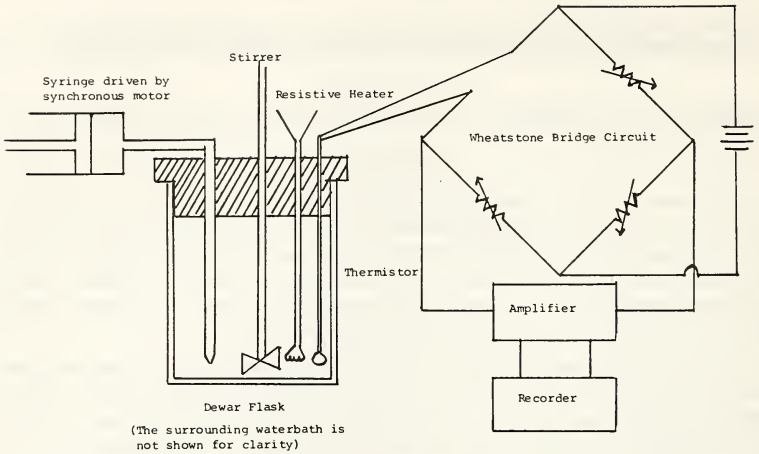

FIGURE 1: *The Complete Apparatus*

indicating little or no temperature rise prior to the titration; point B is where addition of titrant starts; point C is where the reaction concludes and is usually determined as the intersection of BC and CD. Finally, CD is the post-titration portion of the curve and usually corresponds to an excess of reagent. The diagram is read by extrapolating DC to F and then erecting a line at B perpendicular to the volume axis to intersect DC at F, the height, BF, being the temperature increase of the solution at zero volume increase (△ T). The distance, B′E′, along the volume axis corresponds to the volume of titrant consumed by any analyte present during the titration (△ V).

In order to obtain enthalpy values for any reaction conducted one more measurement has to be made: the heat capacity of the solution (C). This is accomplished by creating a known potential difference (V_H) across a small accurately known resistance (R_H) and measuring the time for which the current flows (t

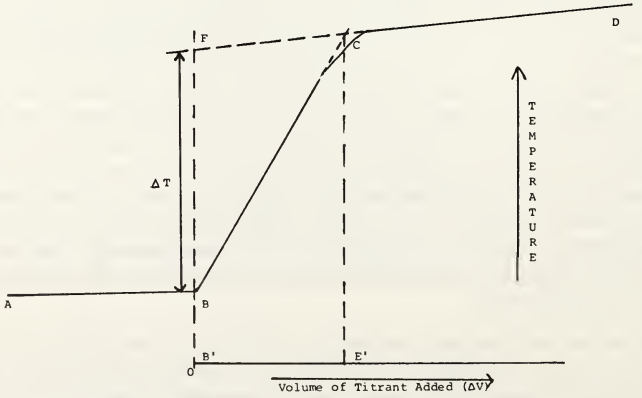

FIGURE 2: *A Typical Thermometric Titration Curve*

seconds). This heat flow will then correspond to a definite rise in temperature ($\triangle T_c$) which may be measured. the calculation is made with the following formula:

$$C = \frac{V_H^2 t}{4{\cdot}184 R_H \triangle T_c} \text{ calories}$$

The enthalpy of the reaction may then be calculated by applying the following equation:

$$\triangle H = \frac{C \triangle T}{\triangle n} \text{ calories}$$

where $\triangle n$ is the number of moles of analyte involved in the reaction.

Experimental

Reagents: Acetohydroxamic acid and salicylhydroxamic acid were purchased (Aldrich Chemical Co.) and recrystallized twice from an ethanol-water mixture; N-phenylbenzohydroxamic acid and benzohydroxamic acid were synthesized and purified by the usual methods (4, 7). All melting points were corrected and found to tally with those available in the literature. The sodium hydroxide used was prepared to be about 0.1M and carbonate-free by a suitable method (15) and standardized in the usual fashion (15). All the water used was distilled, deionized and carbonate-free.

Method: Solutions of the acids in water were made containing between 1.0 and 6.0 milimoles per litre and aliquots were loaded into the Dewar flask using a calibrated pipette. The flask was attached to the stopper and then the whole immersed in an external constant temperature waterbath. After thermal equilibrium of the flask and contents was attained, sodium hydroxide solution was introduced using a syringe pump and the reaction monitored by the thermistor circuit. The experiment was repeated several times for each acid at different concentrations and reagent flow rates.

TABLE 1: *Thermodynamic Data for Several Hydroxamic Acids*

Function* / Acid	$\triangle H°$ neut. (Kcal/mol)	pK_a Ref. (6)	$\triangle H°$ dep. (Kcal/mol)	$\triangle G°$ dep. (Kcal/mol)	$\triangle S°$ dep. (Cal/mol/K)
N-phenylbenzohydroxamic acid	-(11.5 ± 0.2)	8.35 ± 0.02	(2.02 ± 0.02)	(11.39 ± 0.03)	-30
Benzohydroxamic acid	-(7.33 ± 0.05)	8.87 ± 0.04	(6.19 ± 0.08)	(12.10 ± 0.05)	-20
Salicylhydroxamic acid	-(8.40 ± 0.06)	7.51 ± 0.05	(5.12 ± 0.03)	(10.25 ± 0.07)	-17
Acetohydroxamic acid	-(8.50 ± 0.05)	9.41 ± 0.01	(5.02 ± 0.03)	(12.84 ± 0.01)	-26

* The items used in the table are as follows:
$\triangle H°_{neut.}$ = standard enthalpy of neutralisation.
$\triangle H°_{dep.}$ = standard enthalpy of deprotonation.
$\triangle G°_{dep.}$ = standard Gibbs free energy of deprotonation.
$\triangle S°_{dep.}$ = standard entropy of deprotonation.

Results and Conclusions

The molar heat of neutralization was calculated for each of the hydroxamic acids and these, coupled with potentiometrically determined acid dissociation constants (16) were used to calculate other valuable thermodynamic data of fundamental importance at a temperature of 298K for the reaction

$$HA \rightleftharpoons H^+ + A^-,$$

and are embodied in Table 1. A brief consideration of this data shows no apparent trend in the values although N-substitution may affect the value for $\triangle H°_{dep}$, the standard enthalpy of deprotonation. However, there is too little data to draw any conclusions as yet and more information must be gathered.

Acknowledgment

The author wishes to thank Dr. Joseph Jordan of the Department of Chemistry at the Pennsylvania State University for the use of research equipment during this project.

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Interactions of Two ADP Analogs, Xanthosine-5′-Diphosphate and 8-Bromoadenosine-5′ Diphosphate, and ADP with Citrated Human Platelet Rich Plasma

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Introduction

It has been well known for twenty years that adenosine-5′-diphosphate (ADP) will cause aggregation of a stirred suspension of platelets in citrated human platelet-rich plasma (PRP) (1, 3). A number of other naturally occurring nucleotides have also been examined for this potential and only deoxy adenosine 5′-diphosphate was shown in early reports to aggregate platelets (3). Later investigations also revealed that two additional ADP analogs could induce platelet aggregation: 3′-deoxy adenosine-5′-diphosphate and the 1-N-oxide of ADP (4).

Tentative conclusions were made that the C-6 amino group of adenine and the pyrophosphate moiety attached to the ribose were essential for these activities to be observed (3, 4). Several investigators have suggested that this event is triggered by the binding of ADP to a discrete platelet membrane receptor (2). The present and earlier investigations in this laboratory have been aimed at evaluating the stereochemical nature of this hypothetical receptor by systematic variation of structural features of the ADP molecule. The two current ADP analogs, xanthosine-5′-diphosphate (XDP) and 8-bromo-adenosine-5′ diphosphate (BrADP) represent structural variants with purine ring modifications.

Materials and Methods

Whole blood freshly collected from normal human subjects was rapidly mixed with one-tenth total volume of 3.2% sodium citrate. Platelet-rich plasma was prepared by differential centrifugation and the microscopically determined platelet count was adjusted to approximately 400,000/mm^3 by dilution with physiological saline (0.155 M NaCl). Both of the present test nucleotides were supplied by P-L Biochemicals Inc., Milwaukee, Wisconsin, and each was dissolved in physiological saline and adjusted to a final pH of 7.

Platelet aggregation was evaluated by the turbidometric method of Born in a Payton Assoc. dual channel aggrogometer (1). Samples of PRP (0.5 ml) were placed in cuvettes and stimulated after 30 seconds by a) nucleotide solutions only, b) nucleotide solutions followed in 30 seconds with an aggregating dose of ADP, and c) nucleotide solutions followed in 5 minutes with an aggregating dose of ADP. The longer incubation intervals were used to maximize opportunities for binding of the analogs to a platelet membrane receptor and also to emphasize any additional events caused by metabolites of these nucleotides under study.

Results

A typical result of additions of BrADP over a 100 fold concentration range to platelet rich plasma suspensions is shown in Figure 1. It can be noted that when physiologic saline (control) only added to PRP that no change occurs in light transmission. If aggregation had occurred, a rapid increase in the light transmission through the solution would have been observed. Similarly when 0.05 ml ali-

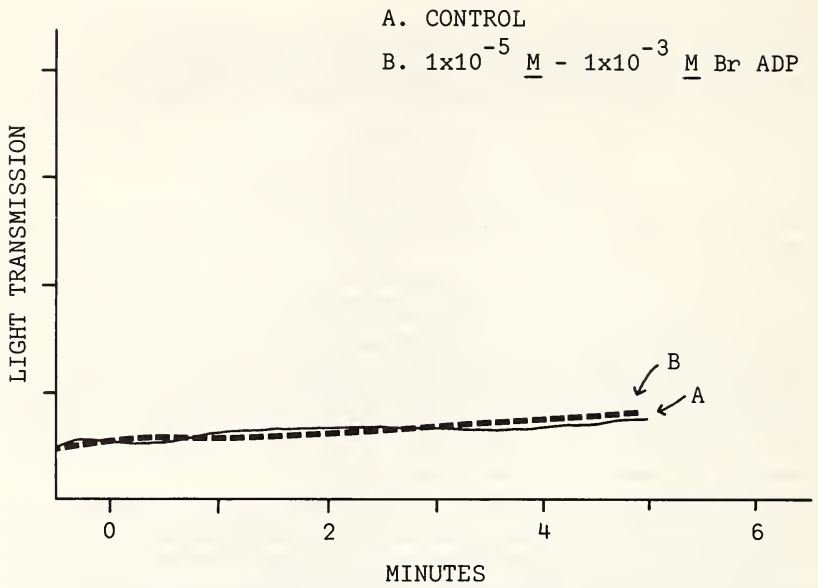

FIGURE 1: *Effects of direct addition of various concentrations of BrADP to human platelet rich plasma.*

quots of BrADP in the concentration range 1 x 10^{-5} M-1 x 10^{-5} M are added, no change in light transmission occurs. Thus, one can conclude that this nucleotide over a 100 fold concentration range failed to stimulate any aggregation of platelets in the PRP suspension for periods of time observed up to 5 minutes. An analogous collection of curves were also obtained when aliquots of XDP were added to PRP over this same concentration range.

In Figure 2, the results of adding ADP alone to platelet rich suspensions are shown by curve A. It can be noted that within 30 to 60 seconds, a dramatic increase in light transmission has occurred and as more platelets are involved in the aggregation, this increase in light transmission begins to slow and eventually levels off in a plateau. If various doses of XDP varied over a 100 fold concentration range are preincubated with PRP for 30 seconds before this aggregating dose of ADP is added, one obtains curves B, C and D. It can be noted in examining these curves that various amounts of XDP failed to yield any competitive inhibition of the ADP induced platelet aggregation. If inhibition were observed, a lag time in the ADP induced aggregation would have occurred and also the magnitude at which the plateau would be observed would have been smaller also. Completely analogous results were observed for BrADP.

In Figure 3, the results of preincubating PRP with BrADP for 5 minute periods before adding an aggregation inducing dose of ADP can be seen. Curve A shows the result of adding a 0.05 ml aliquot of physiological saline only to a stirred suspension, and then adding an aggregating dose of ADP after 5 minute preincubation. It can be seen that the initial light transmission change which is caused by a morphologic change in platelet shape causes a slight increase in light transmission immediately after the ADP is added. Once again, the early phase of aggregation proceeds rapidly with a dramatic decrease in light transmission followed by a slow-

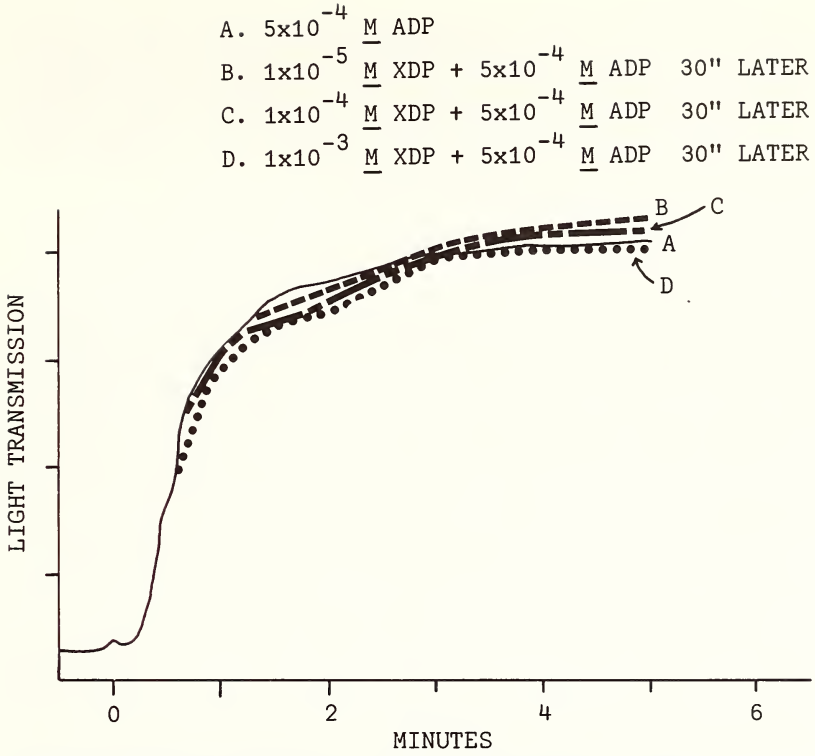

FIGURE 2: *Effects of additions of various concentrations of XDP to human platelet rich plasma, followed by an aggregating dose of ADP after 30 seconds.*

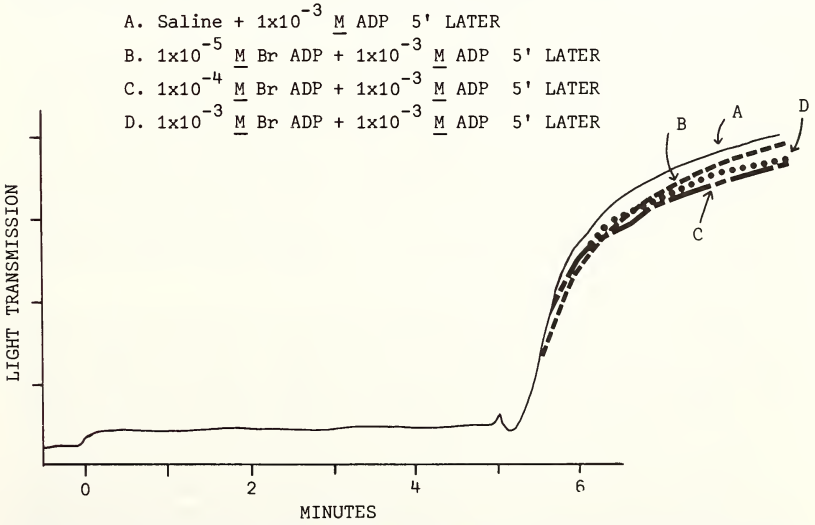

FIGURE 3: *Effects of additions of various concentrations of BrADP to human platelet rich plasma, followed by an aggregating dose of ADP after 5 minutes.*

ing to a plateau after an additional 1 minute period. The shape of this curve A is quite similar to the curve A shown in Figure 2. Finally it can be seen that when BrADP is systematically varied over the selected 100 fold range of concentration preincubated with PRB for 5 minute periods, no inhibition of ADP aggregation is observed. In analagous fashion if XDP is preincubated for 5 minute periods in order to permit membrane linked or metabolic effects to occur, once again, no inhibition of ADP induced aggregation is observed.

Discussion

Several purine modified derivatives of ADP have been reported to be mildly active in the direct aggregation of PRP or in the inhibition of ADP induced aggregation of PRP. In 1972, Gough *et. al.* reported that 2-methoxy adenosine-5′ diphosphate or 2-methylthio adenosine-5′-diphosphate was actually more active on a comparative molar basis than ADP. These authors concluded that substituents at C-2 of the adenine moiety are nicely tolerated with respect to platelet asggregation induction and they also suggest that the C-6 amino group must be present for aggregation to occur. They state that their results are compatable with Born's hypothesis of a specific ADP receptor on the platelet membrane. Unfortunately, their results may not be directly comparable to the present results since they were using sheep PRP and they also did not report any competition studies as has been reported in this present paper (5, 6).

Stone *et al.* report three thiol analogs of ADP with the sulfhydryl groups being attached at either position C-2, C-6 (in place of the amino group) or C-8 (8). When these compounds are added directly to human PRP the following relative activities compared to similar doses of ADP were observed: with the C-2 analog, 74% activity; with the C-8 analog, 0.65% activity; and with the C-6 analog, 0.08% activity. They concluded that substitutions at C-2 of the adenine ring are tolerated but substitutions at position C-8 lead to steric hinderance of binding to the platelet ADP receptor. Finally they conclude that removal fo the C-6 amino group of ADP causes complete loss of activity.

Our present results are in agreement with theirs in that substituents at position C-2 and C-6 as is seen with XDP are not tolerated at the platelet ADP receptor and furthermore our C-8 substituted compound (BrADP) is also not tolerated at the platelet ADP receptor. Robey *et al.* produced one additional C-2 analog to be used in electron spin resonance studies of the interaction of ADP-like substances with platelet membrane receptors (7). This particular compound with a bulky group attached to C-2 was once again found to be active in inducing aggregation of human PRP. This is a rather striking example that very bulky groups can be tolerated at position C-2 of the adenine ring.

Our present results support the concept that there is a discrete ADP receptor on the platelet membrane and that this receptor is sensitive to certain structural changes in the purine moiety of ADP. The lack of effect of XDP on PRP suggests that a substituent similar in size and change to the C-6 amino group of ADP must be present for recognition of the compound by the ADP platelet membrane receptor.

The present results for 8-bromoadenosine-5′-diphosphate also support the conclusion that a bulky group (such as bromine atom) cannnot be tolerated at position C-8 of the purine ring either for correct alignment of the compound on the platelet membrane receptor. The search continues for an ADP-like compound of negligible toxicity which can inhibit the pathologic aggreation of platelets *in vivo*.

Acknowledgments

The author wishes to acknowledge the encouragement and financial support of Dr. P. G. Iatridis for this project while the author was a faculty member of the Northwest Center for Medical Education, Indiana University School of Medicine, Gary, Indiana.

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Evaluation of Detection Systems Used to Determine Lecithin/ Sphingomyelin Ratios in Amniotic Fluid

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Introduction

Hyaline membrane disease has been a major cause of infant mortality and morbidity, especially in infants of low birth weight that have been delivered prematurely. In 1959 it was discovered that certain components were notably deficient in pulmonary surfactant fluid taken at autopsy from infants with hyaline membrane disease. Analysis of pulmonary surfactant revealed that the lecithin levels in these fluid samples were severely reduced (4, 5). Since that time it has been discovered that during fetal development the lecithin is produced almost exclusively by the Type II alveolar cells of the developing fetus (4). Furthermore, this fluid is released into the amniotic fluid contents by ultrafiltration during fetal development, and it was discovered in 1971 that meaningful thin layer chromatographic determination of phospholipids in amniotic fluid could be used as an index for fetal lung development *in utero* (4, 5). Various studies have shown that another phospholipid, sphingomyelin, is produced at relatively constant rates in various compartments and is present at a relatively constant level in the amniotic fluid throughout gestation. In contrast, the production of lecithin increases asymptotically beyond the 34th week of gestation (5).

Statistically, it has been shown that lecithin/sphingomyelin (L/S) ratios in amniotic fluid greater than 2 are indicative of mature fetal lung development before delivery. In 1973, it was determined that treatment with cortisol stimulated the synthesis of lecithin in the developing fetal lung and cortisol treatment along with fetal retentive drugs have been used in permitting the additional normal lung development of fetuses before delivery (4). Obviously, the organic solvent extracts of amniotic fluid could be concentrated and quantitatively determined by a liquid chromatographic method. However, most hospitals have neither the monetary or personnel investment for these kinds of research procedures to become widely used at the present time.

Most of the clinical laboratory methods for determining L/S ratios involve thin layer chromatographic (TLC) separations of various phospholipid components in the organic solvent extracts from amniotic fluid. Finally, a particular detection method is used and the relative cross sectional areas for these two lipid spots compared with various standards migrations are determined. These thin layer chromatographic methods are simple, inexpensive, and rapid to use. Many reports are found in the literature indicating that lecithin and sphingomyelin standards are easily separated (3, 7, 8, 10, 12). Unfortunately, lecithin and sphingomyelin are not as easily resolved from various other phospholipids such as phosphatidyl inositol and phosphatidyl glycerol. There have been suggestions recently that some of these other minor phospholipids may have clinical significance also in assessing fetal lung maturity (6).

Thus, it has been worthwhile to improve the thin layer chromatographic resolution of lecithin and sphingomyelin from other amniotic fluid phospholipids.

This has been approached by the evaluation of various absorbent systems as well as utilization of various resolving solvent mixtures. Finally, a number of detection systems reported in the literature have been evaluated with respect to sensitivity and also linearity of response over a comparable concentration range for each phospholipid. Two fluorescent spray reagents are also evaluated for this purpose.

Materials and Methods

Various phospholipid standards have been purchased from Sigma Chemical Company, St. Louis, Missouri, and have been used throughout these experiments. The compounds include lecithin (LEC) (P-6138), sphingomyelin (SPH) (S-7004), lysophosphatidyl choline (LPC) (L-4129), phosphatidyl ethanolamine (PE) (P-5263), phosphatidyl inositol (PI) (P-0639), phosphatidyl glycerol (PG) (P-2892), and phosphatidyl serine (PS) (P-6641). Various absorbents have also been evaluated for L/S separation, including plates prepared from Brinkmann silica gel G (40 grams per 70 ml of distilled water). After plates were coated with a 250 micron layer, they were permitted to air dry overnight. Other Brinkmann silica gel G plates were activated at 70°C for 30 minutes and stored in a plate desiccator upon returning to room temperature and, finally, some silica gel plates were thoroughly activated by heating at 100°C for 60 minutes and then stored in a TLC plate desiccator. Brinkmann cellulose MN300 was also used to prepare plates with a 250 micron layer which were air dried overnight. The concentration of the slurrry was 15 grams per 90 mls. of distilled water. Brinkmann MN300 cellulose coated sheets with 100 micron layers were also used. Whatman precoated silica gel plates (LK5DF and LK6DF), as well as Whatman high performance silica gel plates (HP-KF) and Whatman KC18F reverse phase plates were evaluated in the present experiments. Organic solvent systems, which were reported in the literature, or developed in our labs include those listed in Table I. The various detection systems reported in the literature or developed in this lab are listed in Table II. The various reagents used in these systems were purchased from Sigma Chemical Company, American Scientific Products, or Fisher Scientific.

Results

Many of the solvent systems listed in Table I have value in separating lecithin standards from sphingomyelin standards on thin layer chromatography plates. Unfortunately, many of these solvent systems incompletely resolve the other phospholipid components from these two principal phospholipids. Many of the phospholipids also show considerable tailing with these various solvent systems. The systems which appear to have the greatest merit include the chloroform/methanol/water mixture (65:25:4) reported by Gluck *et. al.* (1971) (4, 5), and the chloroform/methanol/30% ammonium hydroxide mixture (68:28:4). In all of our experiments, we have used this latter solvent system.

Among the various absorbents investigated, only silica gel G plates coated in our labs were useful for the present purpose. There was a tremendous amount of tailing of most phospholipids on the cellulose plates, and the various Whatman plates were of no value whatsoever for resolution of phospholipids either directly from amniotic fluid samples or from solvent extracts of amniotic fluid samples. Utilizing the silica gel plates, the lowest degree of plate activation was found to be most satisfactory. Thus, for the remaining experiments which evaluated the use of the various detection systems, only silica gel plates which were coated with 250 micron layers and which were air dried overnight were used. The use of silica gel G supplied by other vendors such as Mallinckrodt and Sigma Chemical Company showed no significant differences in resolution or detection sensitivity.

TABLE I: *Solvent Systems Evaluated For L/S Separation:*

CH_2Cl_2:EtOH:HOH (70:16:2) (3)
$CHCl_3$:MeOH:NH_4OH (85:10:1.5) (3)
CH_2Cl_2:EtOH:NH_4OH (70:16:2) (3)
CH_2Cl_2:EtOH:CH_3COOH (70:16:2) (3)
CH_2Cl_2:EtOH:HOH (51.5:12:1.5) (11)
$CHCl_3$:MeOH:HOH (80:30:5) (12)
$CHCl_3$:MeOH:CH_3COOH:HOH (50:30:12.5:5)
$CHCl_3$:MeOH:HOH (95:35:4)
$CHCl_3$:MeOH:30% NH_4OH:HOH (34:14:2:0.75)
$CHCl_3$:MeOH:30% NH_4OH (68:28:4)
$CHCl_3$:MeOH:HOH (65:25:4)
C_6H_6:MeOH (95:5)

(The single numbers in parentheses indicate literature cited.)

Using various amounts of each phospholipid over a 100-fold concentration range, the following limits of detection have been determined for each detection system and for each phospholipid, as is shown in Table III. Finally, the linearity of response of the various phospholipid spot sizes, as concentration is varied, and using each of the detection systems, is shown in Table IV.

Discussion

The use of Rhodamine B spray reagent was reported by Blass *et. al.* (1973) (1) and by Blass *et. al.* (1974) (2). In these two papers, it was indicated that linearity of response for lecithin was observed in the concentration range of 3 to 20

TABLE II: *Spray Reagents Evaluated for L/S Separation*

1) *Rhodamine B* (50 mg) is dissolved in 10 ml methanol. Dark pink spots on a pink background are revealed under a short wavelength UV source.
2) *Phosphomolybic acid* (5 grams) is dissolved in 100 ml of isopropanol/methanol mixture (70:30). After spraying, the plates are heated at 190° for 20 minutes; black spots on a green background are revealed.
3) *Potassium Permanganate* is dissolved as 0.1 *M* solution in distilled water. Spraying yields yellow spots on a violet background.
4) *1-Aniline-8-naphthalene sulfonate* (50 mg) is dissolved in 100 ml distilled water. Under a long wavelength UV source, spots exhibit blue florescence.
5) *2, 7-Dichlorofluorescein* (250 mg) is dissolved in 100 ml distilled water. After spraying, plates are exposed to ammonia vapor for 20 minutes to develop orange-green spots on a yellow background.
6) *Bromothymol Blue* (50 mg) is dissolved in 50 ml distilled water/8 ml of 1 *N* NaOH and diluted to 120 ml final volume with water. pH is adjusted with addition of 1.25 grams of boric acid. Yellow spots are observed on a blue background.
7) *Iodine vapor* saturating a TLC chamber develops brown-yellow spots on plates within 25 minutes.
8) *Cyclodextrin* (#3-4667, Supelco, Inc., Bellefonte, PA 16823) is sprayed directly onto TLC plates and dried for 10 minutes. Exposure to iodine vapor for 20 minutes produced large brown yellow spots.
9) A 50% dilution of concentrated *sulfuric acid* reveals black spots after heating to 120°C for 20 minutes.
10) *1, 6-Diphenylhexatriene* (10 mg) is dissolved in 100 ml of dichloromethane. This reagent yields purple spots under a long wave length UV source.

TABLE III: *Limits of Detection for Various L/S Sprays (In Micrograms)*

	LEC	SPH	LPC	PE	PI	PC	PS
Rhodamine	2	1.5	3	4	–	2	3
Phosphomolyb	1	1.5	1.5	7	0.7	–	1.5
$KMnO_4$	10	2	2	7	1.5	2	0.4
ANS	0.2	1	0.3	0.7	0.7	2	0.4
DC-Fluor	0.4	10	7	–	15	7	3
BR-Thy	2	1.5	0.3	2	1.5	–	1.5
Iodine	4	10	1.5	4	–	–	2
Cyclodex-I_2	0.2	2	0.4	2	–	2	0.3
H_2SO_4	2	1.5	20	–	–	–	10
DPH	0.4	1.5	7	1	0.7	0.3	1

Key to symbols used:
Phosphomolyb = Phosphomolybdic acid
ANS = 1,8-Anilino naphthalene sulfonate
DC-Fluor = Dichlorofluorescein
BR-Thy = Bromothymol blue
Cyclodex-I_2 = Cyclodextrin iodine

TABLE IV: *Linearity of Response for Various L/S Sprays*

	LEC	SPH	LPC	PE	PI	PC	PS
Rhodamine	NI/LS	NI/HS	NI/LS	NI/LS	–	NI/LS	NI/LS
Phosphomolyb	NI/HS	NI/HS	NI/LS	NI/LS	Z/LS	–	NI/HS
$KMnO_4$	NI/LS	NI/LS	NI/LS	NI/LS	Z/HS	Z/LS	NI/HS
ANS	Z/HS	Z/HS	Z/HS	Z/HS	Z/HS	Z/HS	Z/HS
DC-Fluor	Z/HS	NI/LS	NI/LS	–	NI/LS	NI/LS	Z/LS
BR-Thy	Z/LS	NI/LS	NI/LS	Z/LS	NI/LS	–	NI/HS
Iodine	NI/HS	NI/LS	Z/LS	NI/LS	–	–	Z/LS
Cyclodex-I_2	NI/LS	NI/LS	NI/HS	NI/HS	–	NI/HS	NI/HS
H_2SO_4	NI/HS	NI/HS	–	–	–	–	NI/LS
DPH	Z/HS	NI/HS	Z/LS	Z/LS	NI/LS	NI/HS	Z/HS

Key to symbols used:
NI = non zero intercept
Z = zero intercept
LS = low slope
HS = high slope

micrograms, and linearity of response was observed for sphingomyelin in the concentration range of 3 to 12 micrograms. We found this reagent to give somewhat linear response with both phospholipids in the range of 1.5 to 20 micrograms. However, we noticed that there was sufficient background color with this reagent and the linearity of response curves determined for both lecithin and sphingomyelin had non-zero intercepts. The slope of the curve for sphingomyelin was also much steeper than that for lecithin. Finally, we determined that the lowest limits of detection with this spray reagent were 2 micrograms in the case of lecithin and 1.5 micrograms in the case of sphingomyelin. This agrees approximately with Blass *et. al.* (1973) (1) who report a low limit of detection of 1 microgram for both phospholipids. In our present results non-zero intercepts were also yielded by the other phospholipids when Rhodamine B was used as a detection reagent. Also, it is shown that the low limit of detection was not as significant for these other minor phospholipids. Although no results are shown, Blass *et. al.* (1974) indicate that Rhodamine B is more sensitive than 50% sulfuric acid which, in turn, was reported as a more sensitive reagent than bromothymol blue (2). Sulfuric acid charring was also reported by Lemmons and Jaffe (1973) (9), by Morrison *et. al.* (1974) (10), and by Sass *et. al.* (1976) (11). None of these reports give any discussion of sensitivity, selectivity or linearity of response with these particular spray reagent methods.

Our present results indicate that only lecithin and sphingomyelin are significantly detected by bromothymol blue reagent. It can also be seen that lysophosphatidyl choline and phosphatidyl serine are detected by this method but only at ten-fold greater concentrations. The other phospholipids are not even revealed in high concentration by this particular reagent. Furthermore, it is shown in Table IV that the slopes of the linearity of response curves once again have non-zero intercepts. The use of bromothymol blue as a detection reagent is reported by Stuber *et. al.* (1976) (12), once again without any discussion of sensitivity, selectivity or linearity of response for this particular spray reagent.

In our present studies, we found bromothymol blue to be a moderately sensitive reagent yielding linearity of response curves with non-zero intercepts for most of the phospholipids. Iodine vapor was reportedly used by Hallman *et. al.* (1976) as a detection method for phosphatidyl inositol and phosphatidyl glycerol in amniotic fluid (6). We have found iodine to be rather insensitive to low amounts of lecithin or sphingomyelin and iodine also yields linearity of response curves with non-zero intercepts. With the exposure time for iodine that we are presently using, we did not even detect phosphatidyl inositol and phosphatidyl glycerol under these present conditions. Sass *et. al.* (1976) report the usage also of dichlorofluorescein reagent as a detection system (11). They also compare it verbally with other detection methods. They ruled out use of the iodine method because of the iodine toxicity and the fact that the spots fade after a relatively short time period. They also indicated that phosphomolybdate spray gave results that were difficult to reproduce from one series of experiments to another. They concluded in their comparison that dichlorofluorescein was the most useful reagent. We found phosphomolybdate spray to be a relatively sensitive reagent under our conditions; however, the majority of the phospholipids gave linerarity of response curves with non-zero intercepts and variable slopes. Also, phosphatidyl glycerol was not even detected at our highest concentration (20 micrograms) by phosphomolybdate. We disagree about the value of dichlorofluorescein. It seems to be sensitive only in the detection of small amounts of lecithin and phosphatidyl ethanolamine is not detected at all by this particular reagent. Furthermore, the majority of the phospholipids give line-

arity of response curves with non-zero intercepts when this spray reagent is used. Our results also show that a potassium permanganate spray is much more sensitive to small amounts of sphingomyelin than it is to lecithin. The majority of the phospholipids gave linearity of response curves with non-zero intercepts also for potassium permanganate sprays. Also the cyclodextran-iodine detection system designed in this lab was somewhat sensitive for certain phospholipids, but the linearity of response curves were not as encouraging.

The fluorescent compound, 1, 6-diphenylhexatriene (DPH), was reported by Hyslop and York (1980) as a useful reagent for the detection of lipids on thin layer chromatography plates (8). Without showing data, they claim as little as ten nanograms of total phospholipid can be detected with this reagent. We found the reagent to be most sensitive for phosphatidyl glycerol, but the smallest quantity we detected was 300 nanograms. We did however use a different solvent system in which to dissolve the reagent. A report by Heyneman *et. al.* (1972), discusses the use of 1, anilino-8-naphthalene sulfonate (ANS) as a detection reagent (7). The plates were sprayed with this reagent and then scanned with a fluorescence densitometer. Cusick also reports the use of this ANS reagent (3). Of the various reagents investigated in the present report, we have also found that ANS is the most sensitive in terms of lowest limits of detection for the seven phospholipids currently under investigation. We also found that all of the linearity of response curves for the various phospholipids when ANS detection was used gave zero intercepts and all of these curves gave steep slopes over the concentration range reported. We have concluded that the separation of lecithin and sphingomyelin can be easily accomplished on the organic solvent extracts of amniotic fluid and can be easily and semi-quantatively detected on silica gel G plats if ANS is used as a detection reagent. We are currently investigating the actual separation of these phospholipids from amniotic fluid samples and plan to report our results in the future.

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ABSTRACTS

Present Status of Taxodium Distichum (L.) in Hovey Lake, Posey County, Indiana. John Dailey, Jay Craig, Kathy Welborn and Thomas Kozel, Indiana State University, Evansville, Evansville, Indiana 47712.——Hovey Lake, Posey County, Indiana, contains one of the northernmost stands of bald cypress, *Taxodium distichum* (L.) in North America. Few recent studies on the distribution and viability of *T. distichum* at the northern limits of its range are available. This work was begun to determine the distribution and viability of the trees at this limit. Three hundred and fifty nine of the several thousand trees in the 560 hectare lake were selected for study at random using the quadrat method. Core samples, for age determination, d.b.h., spatial distribution and density of the trees in the lake were recorded. These data were analyzed to determine the present status of the species and to allow comparisons with earlier work in the region.

The Fishes of Eagle, Stotts and Rattlesnake Creeks in Central Indiana. W. L. Fisher, Water Resources Laboratory, University of Louisville, Louisville, Kentucky 40292, and J. R. Gammon, Department of Zoology, DePauw University, Greencastle, Indiana 46135.——The fishes of three streams in central Indiana were sampled during the summers of 1978, 1979 and 1980 as part of a Model Implementation Program (MIP) sponsored by the U.S. Environmental Protection Agency and the Department of Agriculture. The goal of the project was to monitor the biota and water quality of two of the three streams in response to improved agricultural land-use practices within the watersheds. Rattlesnake Creek served as a control stream for the study.

One hundred individual collections were made from the three streams during the three-year period. The total number of fish collected during the study was 35,043 representing 11 families and fifty species. Of those fifty species, eight comprised 85% of the total number caught. These species were central stoneroller *Campostoma anomalum*, silverjaw minnow *Ericymba buccata*, striped shiner *Notropis chrysocephalus*, bluntnose minnow *Pimephales notatus*, creek chub *Semotilus atromaculatus*, white sucker *Catostomous commersoni*, johnny darter *Etheostoma nigrum*, and orangethroat darter *E. spectabile*. Mean summer standing crop values ranged from 33 to 320 kg/ha.

The collections at Eagle Creek yielded 37 species, seven of which comprised three-quarters of the total number of fish caught. Those seven species include all those listed above except the silverjaw minnow. Mean summer standing crop values ranged from 42-280 kg/ha.

Forty species of fish were taken from the sampling sites on Stotts Creek.

Eight species accounted for eighty percent of the total catch and include all those mentioned previously except the johnny darter. It is replaced on the list by sand shiner *Notropis stramineus*. Thirty-three to 242 kg/ha of fish represented the range of mean summer standing crop values for this stream.

Collections from two sites on Rattlesnake Creek produced 39 species of fish, the eight most common of which include all those initially mentioned except the white sucker. Northern hog sucker *Hypentilium nigricans* accounted for the eighth species on the list. The mean summer standing crop for the two sites ranged from 44 to 320 kg/ha.

A discussion of some of the factors which influenced the composition and abundance of fishes taken from the various sites is made.

Demographic Structure in Peromyscus leucopus. CHRIS KRUPP, MARK MINER and DAVID T. KROHNE, Department of Biology, Wabash College, Crawfordsville, Indiana 47933.——The spatial and temporal aspects of demographic structure have been studied for the past two years in a population of the white-footed deer mouse, *Peromyscus leucopus*, inhabiting an extensive tract of beech-maple forest in west-central Indiana. A massive live-trapping program samples from approximately 200 acres of habitat in which there are subtle but recognizable vegetation differences and topographic discontinuities. Trapping is sufficiently extensive and intensive to assess the extent of demographic subdivision within the 200 acre tract. Demographic differences between most portions of the study area are minor and not persistent in time. One successional area however, appears to be a dispersal sink. It accumulates animals from all other areas but these animals are unable to persist there for the winter. In the spring it is recolonized with mice from the areas surrounding it. These data suggest that an ecological "population" extends over as much as 200 acres but within such a population, smaller demographic units may exist which have distinct demographic patterns. Genetic subdivision of these populations will also be discussed.

Vegetational Changes at the Grants (NM) Volcanic Area after 37 years; A Photocomparison. ALTON A. LINDSEY, Purdue University, West Lafayette, Indiana 47907.——In 1944-48 many photos were taken of biological and geological features of the Grants (NM) Lava Bed, and published in Ecological Monographs, Ecology, etc. Most of these sites were rephotographed in May-June, 1981, under sponsorship of the U.S. Bureau of Land Management, which plans official wilderness status for this 320-square-mile area on the continental divide. There have been noteworthy natural and man-made changes in the 37-year interval. In ice caves in lava tubes a striking recession of the ice mass has occurred, in one case opening widely to access a cavern completely obstructed earlier by an ice plug holding up a meltwater pond supporting a variety of microscopic plants and animals. Potsherds, thick charcoal deposits, and animal and human bones within the cavern depths indicate Indian occupancy, probably during the 900-1300 AD thermal period. Photopairs of ancient, stunted ponderosa pines and pinyons in lava cracks and cinder-cone substrates usually show no detectable growth has taken place since 1948, and even a net loss of biomass in many individuals. Instances of either reproduction or death were very rare. One 230-year-old ponderosa pine, 7 ft. tall, had required 92 years to produce each average inch of diameter growth in wood of the lower trunk. On the windy west or exposed slope of one cinder cone, sizable patches of pine forest have been destroyed by undermining and slippage of ash on the steep slope. In sheltered lava niches, relatively rapid growth of *Parmelia* lichen has drastically eroded the surface of lava rock. Some slight expansion of lichen patches of open surface sites, and

the conspicuous increase of trembling aspen at higher elevations, suggest favorable overall growth conditions. Largely man-made changes are conspicuous in the disruption of sinkhole ponds and marshes, natural wells, and deep pits along new Interstate 40 and the Santa Fe tracks just west of McCartys village. Highway construction where scientific features and rarities, some not known elsewhere in the world, had existed in the Forties has completely destroyed (e.g., the only satisfactory place for observing the optical effect or reflection phenomenon in undisturbed surface bloom of the minute alga *Chlorella*, the stratified myxophycal crust on submerged lava, and the subterranean colony of *Asplenium trichomanes*) or severely damaged (e.g., the emerald green pond bottoms, the red sulfur bacteria forming grossly conspicuous expanses on pond bottoms, and the habitat for the stonewort alga, *Chara*). All these lava bed sites would have easily been spared by placing I-40 alongside the old Rt. 66 to the south side instead of the north. Former population of bats in dry caves have been decimated by disturbance in central parts of the flow, the only part where they were known of, but overall other forms of wildlife seems to have increased. The 396 photos and descriptive report on them are stored at the BLM office at Socorro NM.

Availability of Lipid-Soluble Vitamins in Freshwater Ecosystems: Contributions from Plant Decomposition and Algal Secretion. J. R. LITTON, JR., Department of Biology, Saint Mary's College, Notre Dame, Indiana 46556.——During the 1977-80 period estimates of the contributions of lipids from decomposing plant material and algal excretion to the total lipid fraction (particulate and dissolved) in freshwater Vermont and New Hampshire ecosystems were made. A detailed component of this study was a determination of lipid-soluble vitamins, and their provitamins — compounds of potential significance in the life cycles of herbivores — that were made available in the water column. Fresh samples of mixed phytoplankton, mixed filamentous algae, *Typha*, mixed leaf litter, *Lemna*, *Potamogeton*, and cultured algae (*Zygnema* and *Chlorella*), treated variously, were allowed to decompose in jars of distilled water under aerobic conditions over a 40 day period. The contents of each jar was monitored regularly over this period and the lipid-soluble vitamin concentrations in the water determined. In general, these compounds were both rapidly released into the dissolved fraction and subsequently quickly decomposed by the decomposing plant material. They were more gradually released into the particulate organic fraction and their concentrations remained more stable for the duration of the experiments. These results are correlated with levels of these vitamins detected in the late summer in natural water samples from northern New England.

Laboratory cultures of *Zygnema* and *Chlorella* were monitored over a four week period to determine whether these same lipid-soluble compounds were also available from algal secretion. Cell-free supernatants from these cultures were examined over this period for the presence of these compounds or their precursors. Regular and intensive log-phase samples showed appreciable concentrations of vitamin E (α-tocopherol) in the supernatant. Secretation of lipid material may be an additional source of lipid-soluble compounds in freshwater.

Differential Responses of Male and Female Mallard Ducks to Decoys. K. MARK LOYD, Ball State University, Muncie, Indiana 47306.——Mallard duck responses to decoys were studied during November and December, 1980, at Muscatatuck National Wildlife Refuge. Field tests employing three variations in mallard decoy sex ratios (50:50, 0:100, 100:0) of males and females were utilized. The number of ducks responding to these decoys was compared to those of the local population. Results

suggest that neither male nor female mallards responded out of proportion to their occurrence in the local population. Comparisons of responses between male and female mallards to decoy location, decoy sex ratios, and approach to decoys indicated no statistical differences. However, all mallards showed a preference for an open water decoy location and for a mixed sex decoy group.

Additions of the Flora of Spencer County, Indiana. WILLIAM E. MCCLAIN, Division of Forest Resources and Natural Heritage, Illinois Department of Conservation, Springfield, Illinois 62706.——A floristic study was conducted on an industrial site near Rockport in Spencer County, Indiana. As a result of this investigation, 92 vascular plant species not previously known from Spencer County are reported. Including the plants reported here, the vascular flora of Spencer County totals 667 species, including 16 ferns or fern allies, 1 gymnosperm, 472 dicots and 180 monocots. A significant distribution record is reported for *Orobanche ludoviciana* Nutt., and *Gerardia fasiculata* Ell. and *Anoda cristata* (L.) Schlecht. are new to Indiana.

Additions of the Flora of Sullivan County, Indiana. WILLIAM E. MCCLAIN, Division of Forest Resources and Natural Heritage, Illinois Department of Conservation, Springfield, Illinois 62706.——A floristic study was made of an industrial site located west of Fairbanks in Sullivan County, Indiana. As a result of this investigation, 188 species of vascular plants not previously known from Sullivan County are reported. This increases the vascular flora known from Sullivan County to 721 species, including 15 ferns or fern allies, 1 gymnosperm, 201 monocots, and 504 dicots. New distribution records are reported for *Naias minor* All., *Juncus secundus* Beauv., *Spiranthes ovalis* Lindl., and *Liparis loeselii* (L.) Rich.

An Economic Evaluation of Four Fishing Ponds in the Hoosier National Forest. H. E. MCREYNOLDS, U. S. Forest Service, Bedford, Indiana 47421.——For the past 4 years, the U. S. Fish and Wildlife Service, under a tripartite agreement with the Forest Service and Indiana Department of Natural Resources, has been surveying and renovating small fishing ponds in the Hoosier National Forest. Although use and harvest of larger impoundments on the Forest have been assessed, the small ponds had no creel census until 1980.

In 1980, the Hoosier National Forest contracted with Ball State University to conduct a creel census of 4 selected fishing ponds. Criteria for selection of these study ponds were (1) that the two ponds of each pair would be in the same general locality (to minimize travel costs and time), and (2) that (of each pair of ponds) one would have easy access, and the other more difficult access.

Anglers at the 4 ponds were interviewed during 1980 (April 19-October 20) and a variety of use, harvest, and preference date were collected. These data provided an opportunity to measure the economic value of these ponds. Several conclusions can be drawn from the economic data, the basic one being that this pond fishing resource is monetarily competitive with other Forest resources.

The Degree of Likeness of Interbasin and Intrabasin Fish Faunas as Measured by Similarity Coefficients. H. E. MCREYNOLDS, U. S. Forest Service, Bedford, Indiana 47421.——The implicit assumption has been that the greater the geographic proximity of stream basins, the greater the likelihood that their fish faunas will be more alike. This thesis has been generally based on untested logic rather than formalized investigation and controlled comparisons.

It appears that similarity analysis could be applied to fish fauna data of stream basins with varying degrees of proximity. Interbasin similarity gradients could be

determined. Additionally, use of similarity coefficients could aid in determining the degree of likeness of the fish faunas of different tributaries within the same basin (intrabasin similarities). Results indicate that the seemingly logical assumptions of the past (correlated similarity-proximity gradients) are not conclusively supported by similarity analysis, especially in interbasin comparisons.

Seasonal Succession and Productivity of Phytoplankton in Lake of the Woods and Lake Waubee. CRAIG A. NELSON, and W. HERBERT SENFT II, Department of Biology, Ball State University, Muncie, Indiana 47306.——Phytoplankton population dynamics of Lake of the Woods and Lake Waubee were studied over a twelve month period commencing in October, 1980.

Both lakes exhibited similar, well-defined patterns of seasonal succession. Following the autumnal overturn the phytoplankton community was dominated by the diatom *Stephanodiscus niagarae* and the green algae *Ankistrodesmus falcatus*. During the early winter months, *Oscillatoria* spp. and *Ankistrodesmus falcatus* dominated the phytoplankton communities of both lakes. In late winter, *Asterionella formosa*, *Stephanodiscus tenuis*, *Cryptomonas* spp., and *Dinobryon sociale* became the dominant species. During spring overturn, the phytoplankton community once again exhibited a diatom pulse consisting primarily of *Asterionella formosa*, *Stephanodiscus niagarae*, and *Stephanodiscus tenuis*. This pulse, however, was more pronounced in Lake of the Woods. In Lake Waubee, *Cryptomonas* spp. and *Dinobryon sociale* replaced the diatoms as dominant phytoplankters. Upon stratification and throughout the summer months, *Oscillatoria* spp. were the dominant algal species in both lakes.

Primary productivity measurements indicate that both lakes are quite productive and can be classified as eutrophic. Lake of the Woods with maximum production values of ca 640 mg $C/m^3/h$ appears to be approximately twice as productive as Lake Waubee (ca 265 mg $C/m^3/h$). Results of algal assay experiments indicate that both lakes are phosphorus limited. Phosphorus additions to the lake water stimulated algal growth while the lake water control (no nutrient addition) did not.

Phosphorus Content of Bottom Sediments from Lake of the Woods and Lake Waubee. KENNETH ROBERTS, W. HERBERT SENFT II, and BYRON G. TORKE, Department of Biology, Ball State University, Muncie, Indiana 47306.——The phosphorus content of bottom sediments from 17 locations in Lake of the Woods and 18 locatons in Lake Waubee was determined. Samples were collected using scuba, and both shallow water and deep water areas were surveyed. Total phosphorus concentrations in sediment interstitial waters ranged from 493 to 3363 $\mu g\ l^{-1}$ in Lake of the Woods and from 90 to 3159 $\mu g\ l^{-1}$ in Lake Waubee. Acid-nonlabile sediment bound phosphorus ranged from 94 to 1053 μg (g dry weight)$^{-1}$ in Lake of the Woods and from 67 to 1687 μg (g dry weight)$^{-1}$ in Lake Waubee.

Zooplankton Populations of Lake of the Woods and Lake Waubee. BARRY SALERNO and BYRON G. TORKE, Department of Biology, Ball State University, Muncie, Indiana 47306.——Zooplankton populations of Lake of the Woods and Lake Waubee were sampled over a six month period beginning in March, 1981. Vertical sample hauls were collected at a deep and shallow station in each lake using a #20 mesh plankton net. During the spring months, the rotifer *Keratella cochlearis* dominated the zooplankton community of both lakes. *Keratella cochlearis* maintained dominance during the summer in Lake of the Woods. In Lake Waubee, however, *Kellicottia longispina* and *Conochilus* sp. increased as the summer progressed. In both lakes, rotifers composed a significant portion of the zooplankton community.

Growth and Abundance of Aquatic Macrophytes in Lake of the Woods and Lake Waubee. W. HERBERT SENFT II, TRACY DUNN, and BYRON G. TORKE, Department of Biology, Ball State University, Muncie, Indiana 47306.——Aquatic plants of Lake of the Woods and Lake Waubee were sampled from May through August, 1981. Species diversity was low in both lakes. The dominant species in Lake of the Woods was Eurasian mil-foil *Myriophyllum spicatum*, and it reached maximum densities of 183 g dry weight m^{-2} during peak abundance in early July. The macrophyte flora of Lake Waubee was more diverse and included *Potamogetan crispus*, *Potamogetan pectinatus*, *Ceratophyllum demersum* and the ubiquitous *Myriophyllum spicatum*. Biomass densities reached 359 g dry weight m^{-2} during peak abundance. By late July, macrophyte biomass began to decline in both lakes.

Management and Restoration Strategies for Lake of the Woods and Lake Waubee. W. HERBERT SENFT II and BYRON G. TORKE, Department of Biology, Ball State University, Muncie, Indiana 47306.——Following detailed limnological surveys, proposed management and restoration plans have been developed to improve the water quality of Lake of the Woods and Lake Waubee. Management strategies for Lake of the Woods currently focus upon two restoration alternatives. Macrophyte harvesting has been suggested to help increase the recreational usage of the lake. Sewage diversion of cottage owners' septic fields is proposed to divert a large phosphorus input to the lake. Restoration plans for Lake Waubee focus upon controlling streamflow nutrient input by the construction of holding ponds for nutrient absorption and/or precipitation. Chemical sediment treatment may also be used to prevent internal phosphorus recycling.

Diagnostic-Feasibility Studies of Lake of the Woods and Lake Waubee. W. HERBERT SENFT II, BYRON G. TORKE, PAUL GLANDER, ROBERT HUNCHBERGER and KENNETH ROBERTS, Department of Biology, Ball State University, Muncie, Indiana 47306.——Two public lakes in Indiana—Lake of the Woods, Marshall County, and Lake Waubee, Kosciusko County—have been the focus of intensive limnological studies over the past year. Sponsored by the Clean Lakes Program of the Environmental Protection Agency, these diagnostic-feasibility studies have focused on identifying and quantifying the major nutrient sources of each lake. Extensive tributary and in-lake sampling was begun in November, 1980, and continued through August, 1981. Information from this sampling effort has been used to develop a management and restoration plan for each lake.

Hydrologic and Nutrient Budgets for Lake of the Woods and Lake Waubee. W. HERBERT SENFT II, BYRON G. TORKE, PAUL GLANDER, ROBERT HUNCHBERGER, and KENNETH ROBERTS, Department of Biology, Ball State University, Muncie, Indiana 47306.——Hydrologic and nutrient budgets have been formulated for Lake of the Woods, Marshall County, and Lake Waubee, Kosciusko County. Lake of the Woods has a volume of 7.848×10^6 m^3 and a residence time, T_w of 1.17 years. The measured areal phosphorus and nitrogen loadings to Lake of the Woods are 0.616 g m^{-2} y^{-1} and 49.66 g m^{-2} y^{-1}, respectively. Lake Waubee has a volume of 6.017×10^6 m^3 and a residence time, T_w, of 0.72 years. The measured areal phosphorus and nitrogen loadings to Lake Waubee are 0.770 g m^{-2} y^{-1} and 106.4 g m^{-2} y^{-1}. Streamflow inputs of nutrients are the dominant external sources for both lakes. Septic input is minimal for Lake Waubee, but contributes 22% of the external phosphorus loading to Lake of the Woods. In addition, Lake of the Woods appears to have substantial internal phosphorus loading from the sediments.

The Influence of Fly Ash on the Lake Charles East Zooplankton Community. DAVID F. SPENCER, Indiana University-Purdue University, Indianapolis, Indiana 46205, HUNG YIU YEUNG, and RICHARD W. GREENE, University of Notre Dame, Notre Dame, Indiana 46556.——The zooplankton community in Lake Charles East, Indiana, was sampled from June, 1974 through September, 1977 as part of a lake restoration study. About 1.8 x 10^4kg of lime and 1.8 x 10^6kg of ponded fly ash were added to the lake during May through August, 1975 to precipitate phosphate and seal the sediments. Twenty six zooplankton taxa were observed in samples during the study period. Annual mean species number (5.2-11.3) and annual mean species diversity (H, 0.9-1.3) were highest in 1976, the first year after treatment. By the second post-treatment year these variables had returned to pre-treatment levels. Prior to treatment Cladocera were dominant during fall and early winter (Sept.-Dec. 1974), with Copepoda dominant in late winter and spring (Jan.-May 1975). After treatment Cladocera were dominant throughout the fall and winter (Nov. 1975-May 1976). Copepoda were again dominant in August 1976. The short term effect of the treatment appeared to be termination of the latter part of the copepod annual cycle through elimination of aestivating copepodities in the summer.

Time of Disturbance as a Factor in the Species Composition of a First Year Indiana Oldfield. EDWIN R. SQUIERS, Department of Biology and Environmental Science, Taylor University, Upland, Indiana 46989.——The effect of the date of fallowing on the community structure of a first year oldfield was studied on a series of replicate 7 x 7 meter square subplots in each of six plots in a randomized complete block design at the Taylor University Field Research Area. Every two weeks from the first of May to mid-July 1980 a set of six subplots, one from each plot, was tilled to a depth of 20 cm. Density and cover data were collected for each plant species from 15 randomly located quadrats (0.5 x 0.5 meters square) in each treated subplot at the peak of the growing season. Two-way analysis of variance was used to assess the relative differences within and between replicate subplots and within and between treatments. The results indicated little or no significant difference between identically treated subplots and highly significant differences between treatments. Major shifts in community dominance were generated by altering the time of disturbance by as little as two weeks. The study lends support to the argument that the community structure of early successional systems is heavily dependent on an interaction between the time of last soil disturbance and the dormancy patterns of the species represented in the seed pool.

Bacteriological Analysis of Water Quality in Lake Waubee and Lake of the Woods, Indiana. CARL E. WARNES, W. HERBERT SENFT II, and BYRON G. TORKE, Department of Biology, Ball State University, Muncie, Indiana 47306.——Bacterial analyses of these two lakes in northern Indiana were conducted over a 5 month period spanning the warmer months of 1981. Membrane filtration techniques were used to determine levels of total coliform, fecal coliforms, fecal streptococci, and *Aeromonas hydrophila* in water and selected sites in the two lakes. The standard plate count technique was employed to determine the total bacterial counts in the water. Samples were taken concurrently with water analyzed for other biological, chemical and physical parameters. Both seasonal and site variations were noted in both lakes. Higher counts were observed in July in both lakes with Lake of the Woods showing higher counts in most instances. On numerous samples greater than 100 fecal coliforms were determined in 100 ml samples. The fecal coliform—fecal streptococci ratios were usually around 0.3 and rarely over a value of 1.0. Deep water samples gave values in acceptable range for recreational use while

tributary samples proved to contain levels of these indicator bacteria showing a very poor level of water quality.

Diurnal Variations in Surface Water Dissolved Oxygen Content and Sediment Oxygen Demand of a Northwest Indiana Stream. RICHARD L. WHITMAN, Department of Biology, Indiana University Northwest, Gary, Indiana 46408.——Forty-eight hour diurnal dissolved oxygen, temperature, and pH analyses were performed monthly at a minimum of 4 stations in Salt Creek, Porter County, Indiana from July through September, 1980. Twenty-four hour diurnal analyses were similarly performed at 5 stations in April, 1981. Triplicate sediment samples at 8 stations, from creek km 5.6 to 39.1, were analyzed for oxygen uptake (by Gilson respirometry), organic content and texture. Nitrate-nitrogen, ammonia-nitrogen, total phosphorus, total suspended solids, specific conductance, pH and dissolved oxygen of surface waters were concurrently obtained.

Diurnal oxygen and sediment oxygen demand analyses suggest that oxygen depletion is greatest at creek km 15.0, or 4.3 km below Valparaiso Combined Sewage Overflow (CSO). Sediment oxygen demand is greatest just below Valparaiso CSO. Short periods of rains experienced during July and September diurnals reveal a plume of low oxygen arising below the Valparaiso CSO station and reaching anoxic conditions at the 15 km oxygen sag point. Dissolved oxygen contents were higher below and above this point. Nutrient content of Salt Creek waters were generally lowest above Valparaiso, rose sharply just downstream of the CSO, and gradually declined thereafter.

Evaluation of Thematic Mapper Data and Computer-aided Analysis Techniques for Mapping Forest Cover

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Introduction

Since the launch of the Landsat-1 satellite in 1972, the value of the scanner data obtained from the Landsat satellites has been clearly established. Forest cover types, hydrologic features, agricultural crops and soil patterns, as well as other land use features can be identified and mapped using this satellite data. Because of the quantitative characteristics of such multispectral scanner data and the very large area covered by each frame of Landsat date (over 8.5 million acres), computer-aided analysis techniques are particularly effective for processing Landsat data.

In 1982, a new generation of satellite scanner, called the Thematic Mapper, will be launched aboard Landsat-D. The Thematic Mapper (TM) will have improved spatial and spectral characteristics as compared with the previous satellite scanner systems (i.e. 30 m vs. 80 m spatial resolution and seven relatively narrow vs. four relatively broad wavelength bands). Because of the significant increase in the quantity of data to be obtained and the improved spectral and spatial characteristics of the TM data, it is important to compare the effectiveness of the proposed new Thematic Mapper to the scanner system on board Landsats 1-3 and to define effective data analysis techniques for processing such data.

Objectives

(1) To compare classification results obtained using the best four bands (out of the seven available TM wavelength bands) to results using the four bands most closely approximating the current Landsat scanner.

(2) To compare the classification accuracy of a per-point Gaussian Maximum Likelihood classifier (which classifies each resolution element independently, according to its spectral characteristics) and a per-field classifier (which incorporates the spatial as well as the spectral characteristics of the data into the classification algorithm).

Background

Previous studies have shown that as the number of wavelength bands used to classify MSS data increases, classification accuracy reaches a point of diminishing returns in relation to the computer time required to classify the MSS data (1). This relationship is clearly demonstrated by Figure 1. Even with recent advances in computer technology and software, however, similar relationships are anticipated when analyzing the Thematic Mapper data to be obtained from Landsat-D. Table 1 shows a comparison of the proposed TM channels with those of the current Landsat MSS system. In addition to the increased number of wavelength bands on the TM, it will also have higher spatial resolution. This will allow it to obtain more detailed spectral information from smaller areas on the ground (i.e. resolution elements or pixels) then has previously been possible (5). However, it is possible that higher interclass spectral variability may be introduced with this increase in

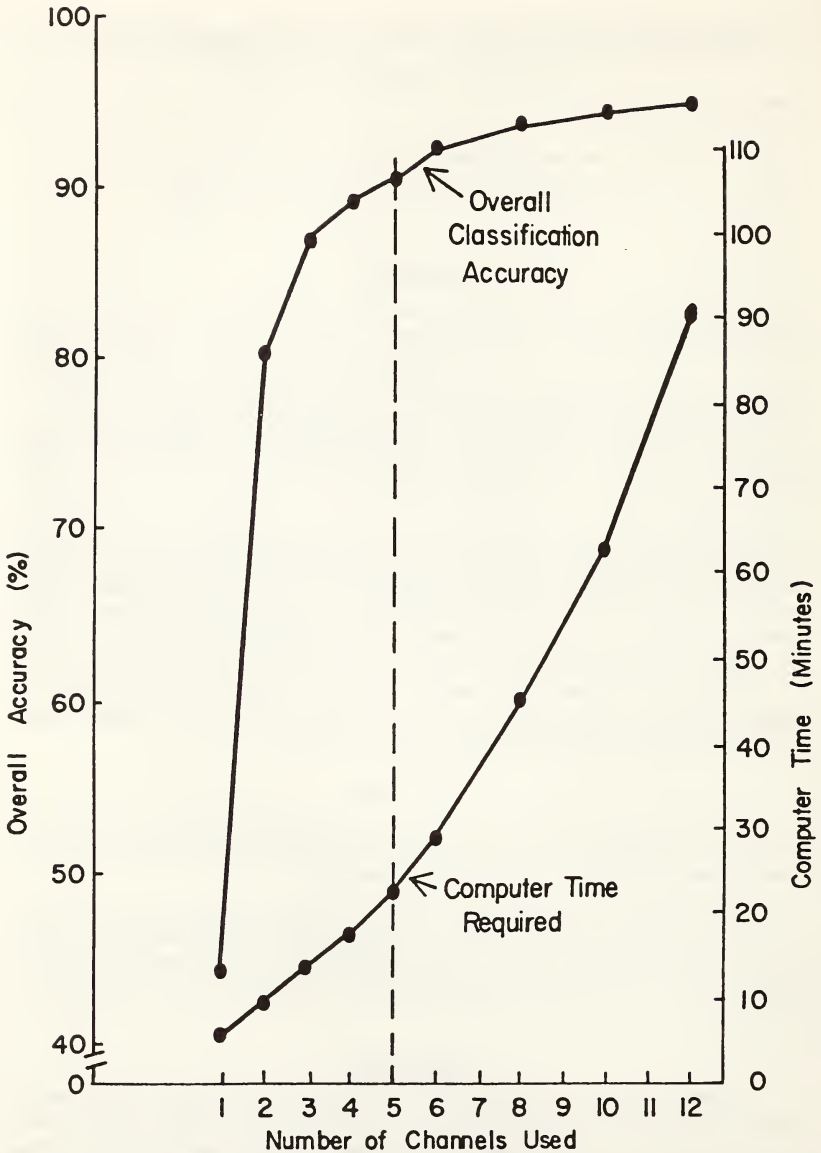

FIGURE 1. *Overall classification accuracy and computer time required in relation to the number of channels used (from Ref. 1).*

spatial resolution, thus increasing the potential for spectral overlap and intraclass confusion.

Materials and Methods

Data for this study consisted of aircraft multispectral scanner data obtained by NASA's NS001 Thematic Mapper Simulator (TMS). The data were obtained on

TABLE 1. *Wavelength Band Comparisons of the Landsat 1-3, NASA NS001 Scanner and the Landsat D Thematic Mapper Scanner systems (wavelengths are in micrometers).*

	Landsat 1-3	NASA NS001 Scanner	Landsat D Thematic Mapper
Visible		(1) 0.45-0.52 μm	(1) 0.45-0.52 μm
Visible	(4) 0.50-0.60 μm	(2) 0.52-0.60	(2) 0.52-0.60
Visible	(5) 0.60-0.70	(3) 0.63-0.69	(3) 0.63-0.69
Near IR	(6) 0.70-0.80		
Near IR		(4) 0.76-0.90	(4) 0.76-0.90
Near IR	(7) 0.80-1.10		
Middle IR		(5) 1.00-1.30	
Middle IR		(6) 1.55-1.75[1]	(5) 1.55-1.75
Middle IR		(7) 2.08-2.36	(6) 2.08-2.36
Thermal IR		(8) 10.4-12.5	(7) 10.40-12.5

[1]On the May 2, 1979 mission, the 1.55-1.75 μm band was not functional, so on the resultant data tape, the 2.08-2.36 μm band was designated as Channel 6 and the 10.4-12.5 μm band was designated as Channel 7.

May 2, 1979 over a study site in South Carolina near the city of Camden. The predominance of large contiguous tracts of forest (primarily bottomland hardwoods), in addition to minimal topographic relief made this a good site for this study. This area has also been designated by the U.S. Forest Service as one of two primary test sites for evaluating various remote sensing techniques for potential use in forest inventories.

Various cover classes (Table 2) were located in the TMS multispectral data by the analyst and class statistics were obtained using a supervised method for

TABLE 2. *Description of the Cover Classes Defined for the Camden Study Area.*

Cover Class	Description of Cover Class
TUPELO	Water tupelo; generally restricted to narrow ox-bow lakes and other areas of inundated soils.
CROP	Row crops and small grain crops in varying stages of development and maturity.
PASTURE	Pasture and old fields; plant cover varies from healthy improved pasture grasses to senescent forbs and invader species.
SOIL	Bare soil areas associated with agricultural activities; varies in sand, clay, and organic material content as well as moisture content.
HARDWOOD	Old age bottom-land and second growth hardwood; sweetgum is the dominant species in the older age classes with a diverse species composition in the younger age classes.
CLEARCUT	Areas subjected to clearcut forestry practices; ground cover comprised of dry to inundated soils without vegetation, to dense vegetative cover of slash, grasses, shrubs and residual trees. Windrowed slash is common.
PINE	Pine forest areas; the principle species is slash; longleaf, and loblolly are common; age class varies from recently planted (5-10 years) to mature, closed canopy.
WATER	Water; primarily associated with the Wateree River (approximately 70-90 meters in width). Other areas comprising the water class are associated with surface mining and open marsh.

developing training data (1). The computer-generated statistics from the training fields consist of the means and variances of all spectral classes representing the various cover classes in each of the seven channels available. These statistics are used to 'train' the computer and pattern recognition techniques (7) are then applied in order to identify these same spectral classes in the remainder of the MSS data. Test fields of known cover types were also defined for use in evaluating the classification results. These fields were selected using a test grid of dimensions 50 lines by 50 columns. Test blocks, 25 by 25 pixels (i.e. resolution elements) in size, were located in the southwest quadrat of each grid intersection. The largest possible field of every cover type present within each 25 by 25 test cell was located and defined as a test field for that particular class.

To define the 'optimum' four channel subset of the seven available channels, the training statistics were used to define an average transformed divergence (TD) value. This TD value provides a measure of statistical separability of the various spectral classes, and is described in detail in Swain and Davis (7). Pairwise TD values between all spectral classes were averaged for all combinations of four out of the seven TMS channels. The four channel subset with the largest average TD value was then designated as the 'optimum' or 'best' combination for use with this data. Channels 2, 4, 5 and 7 (see Table 1) provided the largest average TD value and were therefore used as the optimum set with which to compare channels 2, 3, 4 and 5, (which were used to stimulate the existing Landsat MSS system) in all subsequent analyses.

The first of the two classifiers used in this study was the GML or Gaussian Maximum Likelihood classifier, a widely used classification algorithm in remote sensing applications. Assumptions upon which this algorithm is based include an absolutely continuous n-variate spectral response vector and multivariate normal class conditional probability density functions (PDF's) (7). Usually these assumptions are not completely satisfied due to the quantification of the spectral response in each channel into distinct response levels, and because of the inherent variability in spectral response of natural cover features. However, deviations from these assumptions are often slight and many classifiers, including the GML, are 'robust' in their tolerance of such violations (4), (7).

The GML classifier is based upon the Bayes' optimal strategy which minimizes the average loss over the entire set of classifications to be performed, i.e. it minimizes the probability of error over the entire data set to be classified and, in so doing, maximizes the probability of correct classification (PCC) (7). In general, this classifier is the most accurate classifier available. However, because the individual pixels are classified based upon spectral information alone, pixels within a particular spectral class may deviate from the class conditional PDF (probability density function) for that spectral class enough so as to be misclassified into another cover class. In other words, one spectral class may represent more than one cover class due to the high interclass variabilities of those cover classes; i.e. significant spectral overlap between two or more cover classes may occur. Consequently, a decision rule such as the GML, which is based upon spectral information alone, may have poor classification performance if there is poor spectral separability between cover classes.

One method of alleviating such difficulties is to incorporate additional information, such as contextual information about adjacent pixels, into the decision rule. The second classifier used in this study, the ECHO (Extraction and Classification of

Homogeneous Objects) classifier, incorporates both spectral and spatial information in the classification sequence and is divided into the following two basic steps:

1) The MSS imagery is partitioned into areas or blocks of statistically similar pixels—a conjunctive approach is used in which small initial n x n homogeneous cells are progressively annexed to adjacent homogeneous cells of similar spectral response until a specified annexation threshold (defined by the analyst) is exceeded.

2) Once the areas of similar spectral characteristics have been determined, statistics representing the PDF's of each of these areas are calculated and compared with the PDF's characterizing all the original m spectral classes, i.e. those spectral classes used to 'train' the computer, and each homogeneous area is then classified, using an extension of the GML algorithm, into that cover class which its PDF most closely approximates.

If at any time a cell of initial n x n dimensions fails a specified homogeneity criteria, then each individual pixel within that cell will be classified using the standard per-pixel GML classifier. For a detailed discussion of the procedure please refer to Kettig and Landgrebe (2), Landgrebe and Erickson (3), and Latty (4).

An arcsin transformation in conjunction with a Newman-Keuls range test was used to compare the classification accuracies achieved (i.e. the PCC values attained) (6).

Results and Discussion

Tables 3, 4 and 5 present the results associated with each of the classifications performed in this study along with the number of test samples and the PCC (probability of correct classification) for each cover class. The PCC for each cover class is found by dividing the sum of correctly classified samples (test pixels) by the total number of text pixels for that cover class. Likewise, overall classification performances are obtained from the sum of all correctly classified pixels from all cover classes divided by the entire number of test samples, i.e. 11,202. Table 6 summarizes the results of all classifications performed and also indicates the results of the Newman-Keuls range test.

TABLE 3. *Classification results based on test field accuracy using the Gaussian Maximum Likelihood (GML) classification algorithm and simulated Landsat wavelength bands (Channels 2, 3, 4, and 5).*[1]

GROUP	No. of SAMPS	PCT CORCT	PINE	HDWD	TUPE	CCUT	PAST	CROP	SOIL	WATER
PINE	775	92.6	718	4	0	35	16	0	0	2
HDWD	7951	89.1	273	7081	174	316	18	8	57	24
TUPE	126	78.3	0	8	94	7	8	2	0	1
CCUT	370	51.4	81	0	0	190	77	1	15	6
PAST	350	71.1	0	28	0	49	249	24	0	0
CROP	324	76.4	0	0	0	3	82	278	0	1
SOIL	1006	90.3	0	0	0	76	15	0	908	7
WATER	300	86.3	0	4	0	32	1	2	2	259
TOTAL	11,202									

$$\text{Overall Performance} = \frac{9777}{11{,}202} = 87.3\%$$

[1]Channel 2 = 0.52-0.60 μm; Channel 3 = 0.63-0.69 μm; Channel 4 = 0.76-0.90 μm; and Channel 5 = 1.00-1.30 μm.

TABLE 4. *Classification results based on test field accuracy using the Gaussian Maximum Likelihood (GML) classification algorithm and the "Best 4" wavelength bands (Channels 2, 4, 5, and 7).*[1]

GROUP	No. of SAMPS	PCT CORCT	PINE	HDWD	TUPE	CCUT	PAST	CROP	SOIL	WATER
PINE	775	91.0	705	4	0	40	26	0	0	0
HDWD	7951	88.0	280	6998	146	375	65	26	60	1
TUPE	126	59.2	0	4	75	7	5	34	0	1
CCUT	370	60.5	48	0	0	224	49	0	49	0
PAST	350	82.6	0	2	1	38	289	20	0	0
CROP	324	77.2	0	1	7	2	63	250	0	0
SOIL	1006	85.6	0	0	0	123	19	0	861	0
WATER	300	78.7	0	3	2	55	1	0	3	236
TOTAL	11,202									

$$\text{Overall performance} = \frac{9638}{11{,}202} = 86.04\%$$

[1]Channel 2 = 0.52-0.60 μm; Channel 4 = 0.76-0.90 μm; Channel 5 = 1.00-1.30 μm; and Channel 7 = 10.4-12.8 μm.

The superscripts in Table 6 indicate the statistical evaluation of the results obtained within a particular cover class and for overall performances of the three classifications using the Newman-Keuls range test at an alpha level of 0.10. Different superscripts indicates that the results for that cover type or for the overall performances were significantly different; those cover types having the same superscripts are not statistically different.

TABLE 5. *Classification results based on test field accuracy using the ECHO classification algorithm and the "Best 4" wavelength bands (Channels 2, 4, 5, and 7).*[1]

GROUP	No. of SAMPS	PCT CORCT	PINE	HDWD	TUPE	CCUT	PAST	CROP	SOIL	WATER
PINE	775	92.9	720	1	0	18	36	0	0	0
HDWD	7951	92.8	169	7382	40	250	92	18	0	0
TUPE	126	60.3	0	9	76	6	3	31	0	1
CCUT	370	58.9	41	0	0	218	65	0	46	0
PAST	350	85.7	0	1	0	35	300	14	0	0
CROP	324	81.5	0	0	8	0	52	264	0	0
SOIL	1006	85.7	0	1	0	120	20	0	862	3
WATER	300	77.7	0	3	2	58	1	0	3	233
TOTAL	11,202									

$$\text{Overall Performance} = \frac{10055}{11{,}202} = 89.7\%$$

[1]Channel 2 = 0.52-0.60 μm; Channel 4 = 0.76-0.90 μm; Channel 5 = 1.00-1.30 μm; and Channel 7 = 10.4-12.8 μm.

TABLE 6. *Summary Comparison of Classification Results (% Accuracy of Test Fields).*

Cover-Type	No. of Samps	Wavebands and Classifier Used: "Landsat" Wavebands,[1] GML Classifier	"Best 4" TM Wavebands,[2] GML Classifier	"Best 4" TM Wavebands ECHO Classifier
PINE	775	92.6%[a][3]	91.0%[a]	92.9%[a]
HDWD	7951	89.1%[a]	88.0%[b]	92.8%[c]
TUPE	126	78.3%[a]	59.2%[b]	60.3%[b]
CCUT	370	51.4%[a]	60.5%[b]	58.9%[b]
PAST	350	71.1%[a]	82.6%[b]	85.7%[b]
CROP	324	76.4%[a]	77.2%[a]	81.5%[a]
SOIL	1006	90.3%[a]	85.6%[b]	85.7%[b]
WATER	300	86.3%[a]	78.7%[b]	77.7%[b]
OVERALL		87.3%[a]	86.0%[b]	89.7%[c]

[1]"Landsat" Wavebands included 2 visible and 2 near infrared wavebands—0.52-0.60, 0.63-0.69, 0.76-0.90, and 1.0-1.3 μm.

[2]The "Best 4" TM Wavebands were defined using a Transformed Divergence Algorithm as a measure of statistical separability. Of the 7 TM Wavebands available, the "Best 4" included 1 visible, 2 near infrared, and 10.4-12.5 μm.

[3]For each cover type, or for the overall classification results, different superscript letters indicate a statistically significant difference, based upon a Newman-Keuls range test with $\alpha = 0.10$. Comparison between Col. 1 and Col. 2 provides an indication of the effect of waveband combination, while comparison between Col. 2 and Col. 3 indicates effect of the classification algorithm used.

The first and second columns of classification results shown in Table 6 compare the Landsat channels with the 'best 4' selected by a maximum average TD value. The second and third columns similarly compare the GML classifier with the ECHO classifier. It is interesting to note that even though the overall performance obtained by the ECHO classifier was significantly better than either of the other classifications, only the Hardwood cover class showed significant difference between the GML and ECHO classifiers using channels 2, 4, 5 and 7. This might indicate that with cover classes of large spectral variability, such as the hardwood category, a significant increase in classification performance can be obtained using a per-field classifier. The other cover classes were much more spectrally distinct, i.e. had lower spectral variability, and hence performed as well using either classifier. The increase in overall classification performance was subsequently a result of the increase in the performance of the hardwood category, largely because the number of hardwood pixels greatly exceeded those of all other categories and therefore carried more weight in the calculation of overall performance. In addition, these results imply certain limitations associated with the average TD values as criteria for selecting an optimal subset of channels; i.e., in this study, even though channels 2, 4, 5 and 7 were chosen as the 'optimal' using an average TD value, channels 2, 3, 4 and 5 (simulated Landsat) still achieved higher overall classification accuracies using the GML classifier. One possible explanation for this is that both the transformed divergence measurement and the GML

classification algorithm incorporate class a priori probabilities in their calculations. In this and many other remote sensing applications, these class a priori probabilities are assumed to be equal, but this is rarely the case. Therefore, those classes with higher class priori probabilities of occurrance may be discriminated against in favor of those classes of lower a priori probabilities, thus resulting in a lower overall classification performance.

Conclusions

The conclusions reached in this study can be summarized as follows:

1) Increased classification performances were demonstrated for some cover types and for the overall classification performance when using the ECHO classifier, as compared to the per-point GML classifier. Although statistically significant, the increased classification performances were relatively small in most cases and may be essentially unimportant from the user's standpoint.

2) The ECHO classifier is particularly effective in classifying those cover types of relatively high spectral variability, such as the hardwood cover class category in this study.

3) For MSS data of higher spatial resolution, such as will be obtained by the Thematic Mapper on Landsat-D, per-field algorithms such as ECHO, which utilize both the spectral and spatial characteristics of the data, should be effective in achieving improved classifications of areas of forest cover.

4) As a measure of statistical separability the transformed divergence (TD) value has certain limitations when applied to MSS data sets and therefore may not be a reliable indicator of the optimum subset of channels to use in the classification if the areal extent of the different cover types involved are significantly different.

Acknowledgment

This research was supported by NASA Contract 9-15889.

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Crayfishes of Lake Wawasee

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Introduction

Lake Wawasee, the largest natural lake in Indiana, is located in Kosciusko County in headwaters of the Elkhart River, a tributary of the Saint Joseph River which empties into Lake Michigan. However, the lake is less than 5 km from the drainage system of the Wabash River which flows into the Mississippi and about 50 km from the Maumee River drainage into Lake Erie. Hay (4) and House (6) reported crayfishes in this region and in 1955 Eberly (2) summarized the status of crayfishes in Indiana which included a complete survey of the literature as well as new state and county records. In 1980 we collected and identified the crayfishes from Lake Wawasee and immediate vicinity, described the habitats, and observed the general population density.

Methods

The specimens were collected with nets, seines, jars and fish hooks baited with meat by wading in shallow water and scuba diving in deep water. The classification of the crayfishes follows that of Hobbs (5).

Results and Discussion

In 1980 four species of crayfishes all in the genus *Orconectes* were collected from Lake Wawasee and the immediate shoreline drainage. The species were, *O. immunis*, *O. rusticus*, *O. virilis* and *O. propinquus*.[1]

Four distinct habitats supported populations of crayfishes. Rocks, rooted aquatic vegetation, debris and mud sheltered the crayfishes in microhabitats. One major habitat was the temporary ponds along the shoreline of Lake Wawasee. The bottom of the ponds consisted of sand and mud which supported dense areas of rooted aquatic vegetation. The only species in the ponds was *O. immunis*. The populations were very large in depths less than 1 m. A second habitat was the drainage stream from the small Pappekeechie Lake into Lake Wawasee. The bottom of this slow moving stream varied from rocky areas at the outlet to sandy at the entrance to Lake Wawasee. A few *O. propinquus* and numerous *O. rusticus* were collected, chiefly from the rocky area. The depth of the water was less than 20 cm and was reddish in color. Eberly in 1955 reported this habitat for *O. rusticus* as a new locality (2).

A third habitat, the fast flowing stream, Turkey Creek, which flows from the southeast into Lake Wawasee had a rocky bottom covered with rooted vegetation. *O. propinquus* was common in this habitat.

The fourth habitat was the shallow areas of Lake Wawasee proper where the bottom consisted of various mixtures of rock, debris, organic matter and mud. Some of the areas extended 40 m from the shoreline. Crayfishes were found in water to depths of 2.5 m. Numerous microhabitats were formed by the crayfishes digging tunnels in the soft bottom and under rocks and debris. The lake habitat supported a few *O. virilis* and numerous *O. propinquus*.

[1] Thanks to Dr. H. H. Hobbs, Jr. for confirmation of the identification of the crayfishes.

Thus *O. propinquus* was the only species found in more than one of the major habitats. It was the single, abundant inhabitant of a rocky bottom, swift inlet, Turkey Creek. *O. propinquus* was common in Lake Wawasee proper along with a few *O. virilis*. This was the only habitat of *O. virilis*. Also *O. propinquus*, small population, co-existed with numerous *O. rusticus* in the inlet from Pappekeechie Lake. *O. immunis* was the abundant single species in the pond habitat.

In addition to the four species of *Orconectes* collected in 1980, records in the literature indicate that one species of *Procambarus* and four species of *Cambarus* have been taken from some habitats in the three major drainage headwaters in the region of Lake Wawasee. *Procambarus blandingii* inhabits both lentic and lotic water (5). It has been collected from Lake Wawasee (3, 4) and habitats in the upper Wabash River drainage (2). *Cambarus diogenes* typically are found in burrows in wet marshes and swamps. This species has been collected from the three major drainage systems in the region of our study (2). Another burrowing crayfish, *Cambarus fodiens* lives in marshy fields, drainage ditches and ponds. The distribution of *C. fodiens* includes all of Indiana and Eberly (2) collected it in ponds and creeks in Kosciusko Co. Housing and industrial developments as well as farming practices have reduced the number of suitable habitats for the burrowing, marsh species. No specimens were found in the immediate vicinity of Lake Wawasee during this study. The distribution of *C. robustus* includes northern Indiana and the species is common in Michigan and Ohio (1, 2). However, there is only one recorded locality in Indiana, the upper Wabash drainage (2). Finally, *C. ortmanni* has been taken from the upper Wabash River drainage.

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Influence of Cutting Management on Nonstructural Carbohydrate Accumulation and Crop Survival in *Medicago sativa* L.

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Introduction

Alfalfa has the potential of producing very high forage yields of excellent quality. Most dairymen prefer to grow alfalfa if soil conditions permit, due to its very beneficial effect on milk production. This is especially true when alfalfa is cut in the bud stage, which usually results in hay or silage with a crude protein concentration of 20% or more.

Cutting alfalfa in the bud stage generally results in a short-lived stand. The premature loss of stand is possibly due to insufficient TNC being stored in the roots (5). The following experiment was conducted to determine the effect of varying lengths of intervals between cutting on the TNC level in alfalfa roots at the beginning and end of winter.

Materials and Methods

Alfalfa cultivar Apollo was seeded at 11.2 kg/ha on 16 April 1976 using a Brillion seedin. The cutting frequencies were initiated in 1977 and terminated in 1980. The alfalfa was seeded on a Chalmers silt clay loam (Typic Haploguall, fine-silty, mixed, mesic) located on the Purdue University Agronomy farm.

The intervals between cuts were 4, 5, 6 or 7 weeks, giving 6, 5, 4 and 4 cuts per year, respectively. Initial cutting dates were 11 May and 1 June. Factorial combinations of interval lengths and initial cutting dates were arranged in eight randomized complete blocks. The individual plots were 1.83 m wide and 6.10 m long. The treatments of one replicate were arranged systematically because that replicate was frequently used for demonstrating to local farmers visible effects of cutting frequency. Fertilizer was applied in two split applications at rates of 112 kg/ha P_2O_5 and 336 kg/ha K_2O, giving an annual application of 224 kg/ha P_2O_5 and 672.60 kg/ha K_2O. The first fertilizer application was made immediately after the first cutting and the second immediately after the last cutting.

Ten alfalfa roots were dug from each plot on 4 December 1979 and 4 April 1980. After harvest, the roots were washed free of adhering soil particles, bagged, and stored at -29°C. This was necessary to halt or at least reduce respiration within the tissues. To eliminate any metabolic tissue breakdown during drying a second treatment was imposed on the roots when they were removed from storage. The frozen tissues were exposed to microwaves in a household microwave oven, after the method of Wolf and Carson (7). The tissues were treated for 30 seconds, after which they were transferred to a hot air oven and dried at 71°C for 5 days before being ground for laboratory analysis. Percent TNC was measured using a procedure outlined by Orwick (2). To determine crop survival or persistence, crowns were counted, using a quadrat with an area of $0.1M^2$ (20 x 50 cm); three such counts were made per plot.

Results and Discussion

Levels of TNC in alfalfa roots harvested on 4 December 1979 and on 4 April 1980 showed only significant difference ($P \leq 0.10$) between early and late cutting

dates in 1979 and no significant differences in the 1980 samples. December-harvested roots were much higher in TNC in all cases than April-harvested roots (Figure 1). In April, the TNC ranged from a low of 22.6% to a high of 25.3%, whereas in the December-harvested roots, the range was 34.5-43.0%. In both years, the alfalfa most frequently cut (every 4 weeks) was lowest in TNC. These results are consistent with the findings of Schmid *et al.* (4), Uhliar (6), and Rai *et al.* (3).

The high TNC levels observed in December 1979 were presumably the result of reduced above-ground physiological activity and increased storage of carbohydrates in the roots during the fall. By 4 April 1980, the levels of TNC had

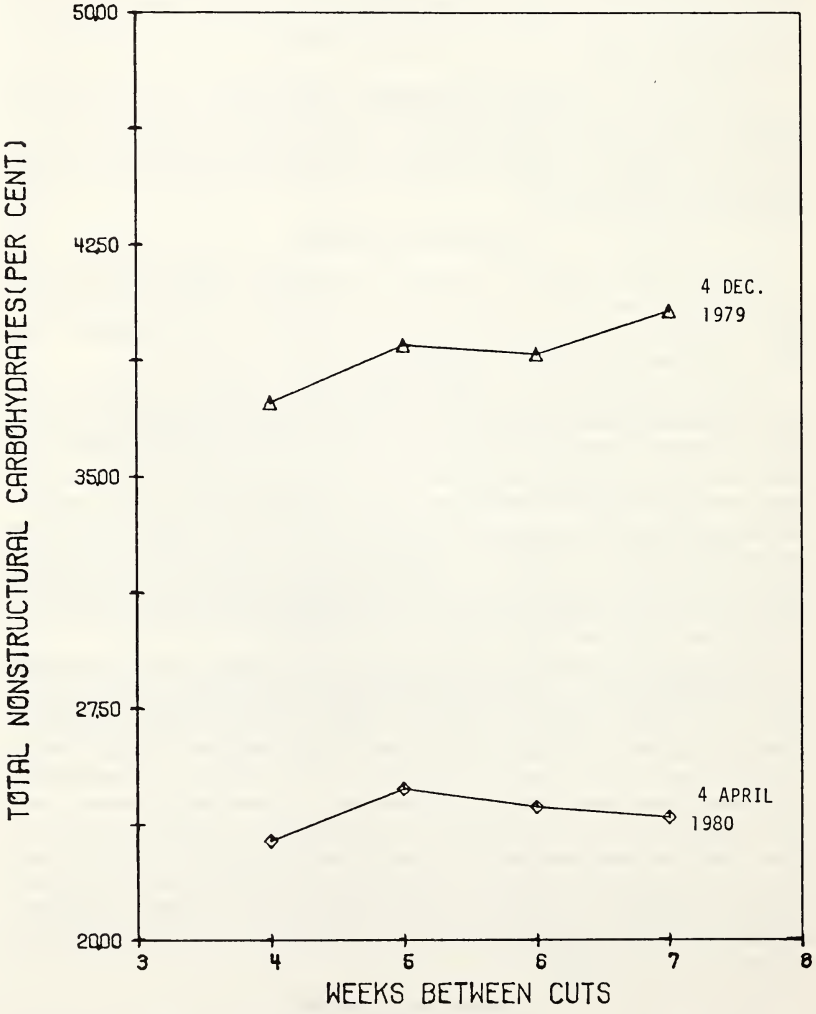

FIGURE 1. *Total non-structural carbohydrate concentrations in alfalfa roots in April and December as influenced by weeks between cuttings.*

TABLE 1. *Alfalfa stand counts at end of experiment, 3 June 1980.*

Treatment		Crowns/0.1m^2
Date 1st Cut	Weeks between cuts	
May 11	4	11.5*
May 11	5	10.7
May 11	6	11.0
May 11	7	11.7
June 1	4	10.3
June 1	5	11.2
June 1	6	10.2
June 1	7	10.8

* Ave. of 6 plots

declined significantly. At this time, due to the warming trend in the early spring, tillers had started forming on stems above, at, and below the surface of the soil. Thus, the plant was now mobilizing nutrients, particularly carbohydrates, from the root reserves and channeling these into the tillers from which new branches and leaves were beginning to develop.

Smith (5) stated that stored carbohydrates are a ready source of food material for winter survival and regrowth in the spring. Other functions of TNC in the plant include the development of cold and heat resistance, survival during dormacy, and the promotion of flower and seed production.

TNC levels increased slightly with decreased cutting frequency in 1979 but not in 1980.

The number of alfalfa plants/0.1m^2 surviving on 3 June 1980 did not vary greatly with the different cutting intervals as shown in Table 1. Number of stems/0.1m^2 might have been a better indicator of stand vigor than plants/0.1m^2.

It was noted that the problem of weeds was more severe in the frequently cut plots, presumably because of less vigorous competition from alfalfa. The major weeds encountered within the less dense plots were crabgrass (*Digitaria sanguinalis*), dandelion (*Taraxacum officianale*), barnyardgrass (*Echinochloa crusgalli*), downy bromegrass (*Bromus tectorum*) and pigweed (*Amaranthus species*).

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Small Mammals of Southern Indiana

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Introduction

From October 1973 through November 1977, small mammals were studied in southern Indiana, intensively on a 1500 ha site near Rockport in Spencer County but also in five other southernmost counties as well. Initially, the objective was to determine the species present on the site (and their relative numbers) because there was not sufficient information on their status to serve as a basis for writing an environmental statement prior to the construction of a facility on the Rockport site. Furthermore, the site needed to be examined for the possible occurrence of any rare, threatened, or endanged species of mammal.

During the first two years, 26 *Sorex longirostris* (southeastern shrew) were taken by pitfall trapping. Because this shrew was considered to be threatened by some nearby states and was being evaluated for endangerment in Indiana, a third study sought to answer the question of whether the rarity of this shrew elsewhere may have been due to the methods of study rather than to actual low numbers. Finally, a fourth study examined whether the 1500 ha site was a focus for a locally dense population of *S. longirostris* by trapping in five neighboring counties in southern Indiana. The results of the last study have been reported in greater detail, especially with regard to habitat association and methods of study in (12). In addition, an independent estimate of the kinds and relative abundance of small mammals in the vicinity of the Rockport site was made possible by the discovery of a barn owl (*Tyto alba*) nest and roost site located nearby. Together, these studies provided the necessary information for the site as well as much valuable information on the mammals of southern Indiana. These studies identified local abundances of southeastern shrews and southern bog lemmings, new distribution records for at least 4 species, detailed information on the relative efficiencies of snap and pitfall traps, and much specific information on small mammals of forest and oldfield study plots.

Most of the intensive studies of mammals were conducted on the 1500 ha site, located in Spencer County in the unglaciated part of southern Indiana, or in the Shawnee Section of the Interior Low Plateau (physiographic) Province (3). The site is typical of Spencer County, with about 80 percent of the area under cultivation. Bisected by a small creek and lying near the Ohio River, the site also contained patches of floodplain and terrace forest, riparian strips and fencerows, but relatively few oldfields.

Description of the Study Areas

On the Rockport site, 8 oldfield and 7 forest plots were studied (Figure 1). During 1973 and 1974, quantitative and qualitative information was collected on the vegetation of 6 study plots (Plots H, I, J, K, L, O) then in use. (A detailed account of the vegetation of Spencer County is in preparation by W. McClain.) The 9 remain-

[1] Work was performed while investigator was at WAPORA, Inc. 6900 Wisconsin Avenue, Washington, DC 21015.

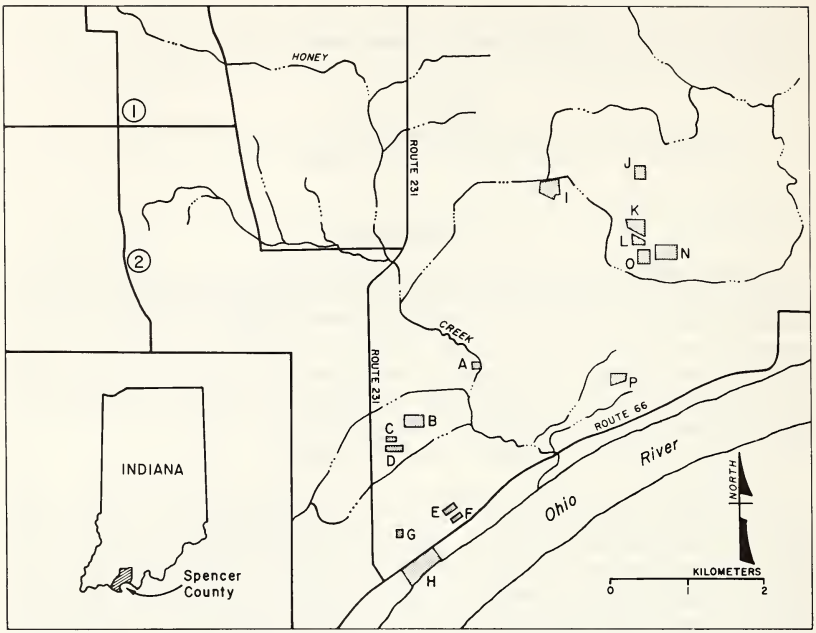

FIGURE 1. *The location of the 15 study plots (Letters A through N) on which the small mammals were studied on the Rockport site, Spencer County, Indiana. Location 1 was the site of the nest and roost for a barn owl, and the number 2 designates the location of a colony of eastern woodrats.*

ing plots, added in 1976 and 1977, did not have extensive vegetational studies. Brief remarks on the vegetation of the study plots follow.

Plot A is a low-lying oldfield located near Honey Creek. Goldenrod, ironweed, asters, horse nettle, trumpet creeper, and ground cherry were interspersed in a dense cover of grasses and sedges.

Plot B is a forest that was studied only in the immature section, where 10 m trees formed a continuous canopy. Pin oak, sweetgum, and red maple were predominant and American elm, black cherry, and sassafras were common associates.

Plot C is an oldfield bordered on one side by a mature forest and on other sides by cultivated fields. Path rush, panic grass, and tall goldenrod were the most conspicuous herbs, and red maple, pin oak, and American elm samplings were scattered throughout.

Plot D is a mature forest of veteran trees ranging from 40 to 100 cm dbh (diameter at breast height), and averaging about 20 m in height. The canopy trees were pin oaks, southern red oaks, swamp white oaks, and sweetgums. The subcanopy was composed of small individuals of those species in association with shagbark hickory, American elm, red maple, black oak, white oak, hackberry, and sassafras.

Plot E is an oldfield with an herbaceous cover of meadow fescue and goldenrod, dotted with scattered trees, mostly 1 to 3 m tall. Sweetgum and red maple

saplings were the most abundant trees, but silver maple, persimmon, green ash, and American elm trees also contributed to the discontinuous canopy which covered about 15 percent of the ground.

Plot F is an oldfield with meadow fescue, goldenrod, and Johnson grass as the predominant herbaceous vegetation. Trees were represented by widely scattered saplings of red maple and sweetgum.

Plot G is a forest in which persimmon, blackgum, oak, maple, hickory, and sassafras averaging 25 cm dbh were all abundant. A dense mat of Japanese honeysuckle covered the forest floor.

Plot H is a forest dominated by silver maple and eastern cottonwood, located in the floodplain of the Ohio River. This frequently flooded plot lay adjacent to cropland and the River.

Plot I is a red maple, pin oak forest located on the first terrace of the River. Although sometimes inundated, this mature forest had a well-developed litter layer and a large number of herbaceous plants.

Plot J and K are oldfields dominated by broomsedge, Kentucky bluegrass, and spreading witchgrass. Both plots were subject to periodic flooding.

Plot L is a red maple, pin oak forest located on the first terrace of the River. Sometimes flooded, this forest also had black willow trees, plus numerous red maple seedlings and saplings.

Plot N is an oldfield with goldenrod, path rush, broomsedge, field sorrel, and mountain mint as the herbaceous vegetation. The scattered woody plants included blackberry, saplings of red maple, sweetgum, and green ash.

Plot O is an oldfield lying near a small pond and covered by herbaceous vegetation and prostrate Japanese honeysuckle. Saplings of red maple, pin oak, and sassafras were scattered throughout the plot.

Plot P is a swamp white oak, shagbark hickory forest located on the first terrace. The forest, with trees averaging 35 cm dbh, had a dense ground cover of Japanese honeysuckle.

From August to November 1977, alternating forest and oldfield study plots were established at 6 km intervals along 280 km of the Ohio River. In all, 26 forested and 25 oldfields plots were placed within 4 km of the River in the 6 counties in southwestern Indiana (locations given in 12:433). In this study, forests were defined as areas with trees 10 cm or more dbh and at least 15 percent covered with shrubs. Oldfield sites had perennial herbaceous plants, such as goldenrods, asters, and broomsedge, and never had more than 15 percent of the area in shrubs or saplings.

Materials and Methods

In 1973 and 1974, the small mammals were collected using Museum Special snap traps, placed at 10 m intervals in transects within each study plot. The traps, baited with peanut butter, were examined daily for four mornings each month. (The southeastern shrews caught during this period were obtained in pitfall traps used to collect ground-dwelling insects).

From April 1976 through February 1977, each study plot (B, D, E, F, N in Fig. 1) was divided into 2 20 m by 20 m subplots, each with 9 trapping stations set 10 m apart. One pitfall and 2 snap traps were placed at each station. The pitfall traps, 160 mm polyethylene jars with 78 mm mouths, were buried with the top flush with the soil surface, half-filled with water, but unbaited. Run for 4 nights each month,

these procedures yielded a gross effort of 3,384 trap-nights for pitfall traps and twice that number for snap traps.

In autumn 1977, small 5 by 7 grids using 5 m intervals were measured on the 51 plots. One pitfall and one snap trap were placed at each intercept. Each study plot was trapped for 3 days during each of 2 periods, except the 7 plots on the Rockport site, which were trapped for 4, and in one instance 5, cycles. In most instances, the cycles were 1 to 2 weeks apart.

Pellets of the barn owl were collected from a roost and nest site located near the Rockport site (Fig. 1). The analysis of the skulls contained in pellets collected in October 1974, January and April 1975, and May and June 1976 provided information on the dietary selection of the owls, and more importantly, an estimate of the availability of the small mammals that were their prey foods.

Results

Ten species of small mammals were trapped during the 1973 and 1974 period (Table 1). Short-tailed shrews, southeastern shrews, white-footed mice, and house mice were obtained from all 6 study plots. Least shrews and prairie voles were restricted mostly to oldfields, and white-footed mice mostly to forests. Eight species of small mammals were taken by concurrent snap- and pitfall trapping in April 1976 to February 1977 (Table 2).

In the autumn 1977 study, 454 small mammals, comprising 10 species, were obtained by the concurrent methods (12:Table 3) in the 6 counties. The white-footed mouse, with 213 individuals, and the prairie vole, with 78 individuals, constituted 47 and 17 percent of the total. Other species in decreasing order of numbers were short-tailed shrew, house mouse, woodland vole, southeastern shrew, meadow jumping mouse, masked shrew, least shrew, and southern bog lemming.

TABLE 1. *Kinds and relative abundance (in %) of small mammals obtained by snap trapping on 3 forest and 3 oldfield study plots in Spencer County, Indiana during 1973 and 1974. Nomenclature follows (7).*

	Forest Study Plots							OldField Study Plots						
	H		I		L			J		K		O		
Species	%	No.	%	No.	%	No.	TOTAL	%	No.	%	No.	%	No.	TOTAL
Sorex longirostris	0.2	1	1.4	1	2.5	2	4	2.7	6	1.6	6	9.5	11	23
Blarina brevicauda	2.6	15	7.2	5	17.7	14	34	21.9	48	0.8	3	12.9	15	66
Cryptotis parva	0.3	2	1.4	1			3	11.4	25	7.8	30	0.9	1	56
Peromyscus leucopus	53.9	310	84.1	58	70.9	56	424	3.7	8	1.8	7	12.1	14	29
Microtus ochrogaster	6.6	38			1.3	1	39	21.0	46	82.3	317	62.1	72	435
Microtus pinetorum					1.3	1	1			0.3	1			1
Symaptomys cooperi	0.5	3			1.3	1	4	0.5	1	0.5	2	0.9	1	4
Rattus norvegicvus	0.9	5					5							
Mus musculus	35.0	201	5.8	4	5.1	4	209	36.1	79	4.9	19	0.9	1	99
Zapus hudsonius								2.7	6			0.9	1	7
TOTAL		575		69		79	723		219		385		116	720

TABLE 2. *Numbers of small mammals captured in snap traps (ST) and pitfall traps (PT) on the oldfield and forest study plots on the Rockport, Indiana site from April 1976 to February 1977.*

	Oldfield Study Plots									Forest Study Plots				
	E		F		N		O			B		D		
Species	ST	PT	ST	PT	ST	PT	ST	PT	TOTAL	ST	PT	ST	PT	TOTAL
Sorex longirostris		3						2	5		2		2	4
Blarina brevicauda	10	1	4				9		24	3	6	5	2	16
Cryptotis parva	16	10	17	5	5	4	3	2	62				1	1
Peromyscus leucopus	14		7	1			42	10	74	52	5	51	8	116
Microtus ochrogaster	2	5	7	3	14	4	1	7	43		1	1	3	5
Synaptomys cooperi	3	2	11	9	5	3	3	2	38					
Mus musculus	5		42	2			1		50					
Zapus hudsonius		2	1						3	1		2		3
TOTAL	50	23	89	20	24	11	59	23	299	56	14	59	16	145

A comparison of trapping efficiency (12:Table 3) indicated that pitfall traps were effective at sampling 7 of the 10 species. However, 3 of the common species, white-tailed mouse, house mouse, and prairie vole, were captured more efficiently in snap traps. Table 3 shows the composite results of both concurrent trapping

TABLE 3. *The number and percentage of small mammals obtained by concurrent snap- and pitfall trapping methods, including the 1976-1977 studies of the Rockport site and the study of 280 km of Ohio River in autumn 1977. The decimal amounts result from the standardization of the number of functional snap and pitfall traps during the 1976-1977 study. The numbers in parentheses are the non-adjusted number of trap nights.*

	Snap Traps (20949)		Pitfall Traps (16617)			
Species	Total number	Percent of captures within a species	Total number (adj.)	Percent of captures within a species	Total No. (adj.)	Percent of captures among species
Sorex cinereus	1	8	12.0	92	13.0	1.3
Sorex longirostris	0	0	33.2	100	33.2	3.4
Blarina brevicanda	42	47	47.2	53	89.2	9.2
Cryptotis parva	43	52	40.2	48	83.2	8.6
Peromyscus leucopus	351	84	68.8	16	419.8	43.2
Microtus ochrogaster	78	55	64.1	45	142.1	14.6
Microtus pinetorum	5	24	16.0	76	21.0	2.2
Synaptomys cooperi	22	43	29.0	57	51.0	5.2
Mus musculus	90	95	4.4	5	94.4	9.7
Zapus hudsonius	9	35	16.4	65	25.4	2.6
TOTAL	641	66	331.3	34	972.3	100.0

TABLE 4. *Food composition of barn owls (Tyto alba), based on examination of the contents of 527 pellets collected from a roost near the Rockport site, Spencer County, in October 1974, January and April 1975, and May and June 1976, and of food brought to young in the nest in spring 1976.*

	Adult Owls		Food brought to young	
	Total No.	Percent	Total No.	Percent
Blarina brevicauda	96	8.8	15	3.3
Cryptotis parva	68	6.2	2	0.4
Sylvilagus floridanus	1	0.1	1	0.2
Peromyscus leucopus	17	1.6	3	0.7
Neotoma floridana	1	0.1		
Microtus ochrogaster	734	67.0	362	80.3
Microtus pinetorum	2	0.2		
Synaptomys cooperi	159	14.5	64	14.2
Mus musculus	12	1.1	1	0.2
Zapus hudsonius	4	0.4		
Birds, all species	1	0.1	3	0.7
TOTAL	1095		451	

studies, obtained by pooling all of the habitats and standardizing the results to compensate for the unequal number of nights of use of pitfall and snap traps. These results are similar to (12:Table 3), except that proportionately fewer prairie voles were caught in snap traps.

The remains of more than 1500 small mammals of 10 species were identified from the owl pellets and the skeletal remains of mammals brought to feed nestlings (Table 4). The pellets yielded one each of eastern cottontail, *Sylvilagus floridanus*, and eastern woodrat, *Neotoma floridana*, whose presences also were known from the existence of woodrat houses and by direct observation, but not from trapping.

Discussion

Based on the reults of these studies, 11 species of small mammals are known to occur in southern Indiana. These include those listed in Table 1, plus the masked shrew (Table 3).

Overall, the white-footed mouse was the most numerous small mammal in forested plots, and the prairie vole in oldfield plots. These results are consistent with other studies of the species and of the region. For example, Batzli (1) found white-footed mice to be the most numerous small mammal in the floodplain and upland forests near the Sangamon River in Illinois. Batzli reported that although the floodplain appeared to be a more severe and less predictable habitat for mice than the upland, *P. leucopus* was more productive there than in the upland. For several groups of organisms at the Rockport site, including some species of mammals and arthropods, the floodplain forest (Plot H) was also highly productive. Plot H was located adjacent to productive croplands of alfalfa and soybeans. White-footed mice eat insects and other arthropods in season, but rely on seeds, fungi, and other plant material when invertebrates are scarce.

In contrast to the white-footed mouse, the prairie vole eats mostly leaves and stems of herbaceous plants. Prairie voles require forbs in the diet, for Getz et al (6) have shown that in Illinois prairie voles cannot sustain populations when fed only grasses. Consequently, there are well suited to living in the oldfields at the Rockport site, where a mix of grasses and forbs is present. In similar habitats in the Midwest, other investigators (4, 5, 8) also have found prairie voles to be numerically dominant.

The house mouse, *Mus musculus*, usually is present either in oldfields of early successional stage or as a commensal of man, i.e., in barns, corn cribs, sheds, and houses. In oldfields, as the habitat changes from annual grasses and forbs to perennial grasses during the course of succession, microtine rodents become increasingly common, and may displace house mice. The interference by *Microtus* of field populations of house mice has been demonstrated experimentally by DeLong (2), and Lidicker (9) reported the population events of a feral house mouse population declining to extinction in competition with *Microtus*. This adverse effect of *Microtus* on house mouse populations is evident in the reciprocal densities of the 2 species on Plots H, J, K, and O (Table 1). When prairie vole densities are high, as in Plots K and O, house mouse numbers are low.

Eight specimens of the southern bog lemming, *Synaptomys cooperi*, were obtained equally from forest and oldfield plots during the early studies at Rockport (Table 1), and *Synaptomys* ranked seventh of 10 species caught with snap traps. However, the combined snap and pitfall methods yielded 51 specimens, slightly more than half of them taken by pitfalls (Table 3). All were from oldfields. Southern bog lemmings were frequently taken by barn owls (Table 4), and ranked behind only prairie voles in this regard. These 2 microtine rodents are the largest common mammals in the oldfields of the Rockport site, with adults usually in the 35 to 45 g range. Barn owls took 1 southern bog lemming for every 5 prairie voles (Table 4), but snap traps caught 100 times more of the latter than the former in oldfields (Table 1). These results probably mean both that prairie voles are more readily caught in snap traps than are southern bog lemmings, and that barn owls took southern bog lemmings at a greater frequency than expected by their true abundance, probably because of their relatively large size.

During the 1973 and 1974, forest and oldfield plots yielded 1 each of woodland vole (*Microtus pinetorum*) with snap traps, but in the 2 studies with concurrent snap and pitfall trapping, 21 woodland voles were obtained (Table 3). Of the 21, only 3 were from the Rockport site, indicating that they may be more common in some other areas along the Ohio River than there. All but 4 were taken from forested study plots and 16 of the 21 were obtained with pitfall traps. Woodland volves were seldom caught by barn owls (Table 4), another indication that woodland voles are predominantly forest dwellers.

Four species of shrews were taken in these studies, with the short-tailed shrew, *Blarina brevicauda*, the most common. *Blarina* ranked fourth of 10 species in the number of small mammals taken by snap traps (Table 1), it had the same rank in the concurrent studies (Table 3), and was third of 10 species taken by barn owls (Table 4). About 65 percent were obtained from oldfield plots (Tables 1 and 2).

At the Rockport site, all but 4 of more than 100 least shrews (*Cryptotis parva*) were from oldfields, and 2 of those were from the floodplain forest, Plot H, which was vegetationally diverse and lay adjacent to cropland. Whitaker (13) trapped more than 150 *C. parva* in Indiana, all in oldfields.

The 54 southeastern shrews caught in these studies represent one of the few

large samples of this species anywhere. In the concurrent trapping, all were taken in pitfall traps, and 78 percent were caught in oldfields (11). These results reinforce the belief that the supposed rarity of the southeastern shrew may be more a consequence of the sampling methods than the true abundance of the shrew. They also confirm Mumford's (10) belief that it has a spotty distribution; 48 were obtained on the Rockport site. Southeastern shrews, with 12 specimens obtained by concurrent trapping in autumn 1977, were second in abundance at the Rockport site then.

By contrast, no masked shrews (*Sorex cinereus*) were taken at the Rockport site. The majority of the *S. cinereus* were obtained from forested plots in Posey and Vanderburgh counties. Only at one location, in western Spencer County, were both species of *Sorex* taken from the same study plot. The masked shrew, a north temperate species, seems to be restricted to the Wabash and Ohio River Valleys in the southern half of Indiana (10:Fig. 5), except for a relict population of a different subspecies in Ripley County. These studies add Vanderburgh and Spencer counties to the known distribution in Indiana.

Overall, shrews were frequently taken as prey by the barn owls (Table 4), but neither *Sorex* was detected. Despite their small size, shrews constituted about 15 percent of the vertebrate prey of these barn owls.

Mumford (10) believed the meadow jumping mouse (*Zapus hudsonius*) to be rare in the southern two-thirds of Indiana, and he stated that specimens were lacking from the Ohio River Valley. All 7 *Zapus* obtained with snap traps in 1973 and 1974 were taken in oldfields, as were 19 of 24 taken later. Fifteen of the 24 were obtained in pitfall traps in the concurrent trapping studies. *Zapus* was caught in Posey, Vanderburgh, Spencer, Perry, and Crawford counties (12).

The best information for this study is of the Rockport site, where 4 studies found one species to be restricted mostly to forested habitats, the white-footed mouse (84%). This species is probably the most numerous forest mammal in eastern North America, and Mumford (10) considers it to be one of Indiana's most common mammals.

Five species were taken primarily in oldfields at the Rockport site, including least shrew (97%), prairie vole (92%), southern bog lemming (91%), southeastern shrew (78%), and meadow jumping mouse (77%). House mice (42%) and short-tailed shrews (64% in oldfields) showed no clear habitat preferences. All 5 Norway rats (*Ratus norvegicus*) were caught on Plot H.

The studies with concurrent trapping seemed to confirm that southeastern shrews are sampled more effectively by pitfall than by snap-trapping methods. All 27 southeastern shrews, and 12 of 13 masked shrews, were taken in pitfall traps (11). Masked shrews are nearly identical in size, shape, and external features to southeastern shrews. Other species for which pitfall traps proved to be more efficient were short-tailed shrews (74%), woodland voles (76%), and meadow jumping mice (72%). Snap traps were effective in trapping white-footed mice (87%), prairie voles (68%), and house mice (98%). The least shrew and southern bog lemming had so few captures that no evaluation could be made.

In conclusion, the small mammals of Spencer County and five other southernmost counties in Indiana are a diverse assemblage including 4 shrews and 3 microtine rodents. The distribution of some species seemed to be spotty in autumn 1977, when the majority of masked shrews were taken in Posey and Vanderburgh counties, of southeastern shrews in Spencer County, and of woodland voles in Spencer and Perry counties. The results of this study supply new information about local abundance of southeastern shrews and southern bog lemmings, and

new distribution records for meadow jumping mice, eastern woodrats, masked shrews, and southeastern shrews.

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Recreation Land Use Adjacent to an Active Heron Rookery: A Management Study

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During Spring 1981, the National Lakeshore, supported by the Indiana Department of Natural Resources (IDNR) conducted a management study of the northern Porter County great blue heron (*Ardea heriodias*) rookery, in order to develop a land use policy compatible with maintaining this 30 plus year old colony. Specific objectives included determination of colony size, nesting and fledging dates; the impact of recreational activities along the Little Calumet River (170 m south of the Main Colony); and the primary feeding areas.

The first bird arrived March 11 and nest construction and courtship activities were well underway by late March. Two low altitude helicopter flights established that hatching had occured by May 5, and that most young were approaching fledging conditions by June 29. Photographs from the latter flight revealed at least 38 active nests and 108 nestlings. Intrusion impact tests indicated the birds rarely reacted unless the intruders were visible. After the leaf-canopy developed, activities adjacent to the rookery had little, if any, impact; however, intruders beneath the nest trees still created minor disruptions. A monitoring program provided evidence that the herons fed in two main areas southeast of the rookery and along Lake Michigan.

The resulting recommendations to management proposed utilization of the adjacent little Calumet River south bank for fishing and other park activities. The Rookery itself should remain closed.

Introduction

The Heron Rookery Unit (HRU) of the Indiana Dunes National Lakeshore was authorized for incorporation into the park by a congressional act in 1976. The unit, classified as a protected area and closed to the public, has the potential for a variety of recreational uses such as fishing in the Little Calumet River (which is designated as a Salmon Stream as part of the IDNR Salmonid Fisheries Program), study of spring wildflowers (one of the best areas in the National Lakeshore), bird watching and hiking. This study was undertaken to determine a management policy compatible with maintaining the integrity of the colony and providing for public recreational activities.

The portion of land containing the rookery proper is still under control of the Indiana Department of Natural Resources, Division of Nature Preserves. We would like to acknowledge their permission for allowing us to conduct this study.

Study Area and Methods

The heron rookery, active since the early 1950's (Raymond Grow, Pers. Comm.) is situated in a fairly isolated woods surrounded by cultivated fields. This 12 ha woodlot is in Section 26 of Township 37N, Range 5W of northern Porter County, Indiana.

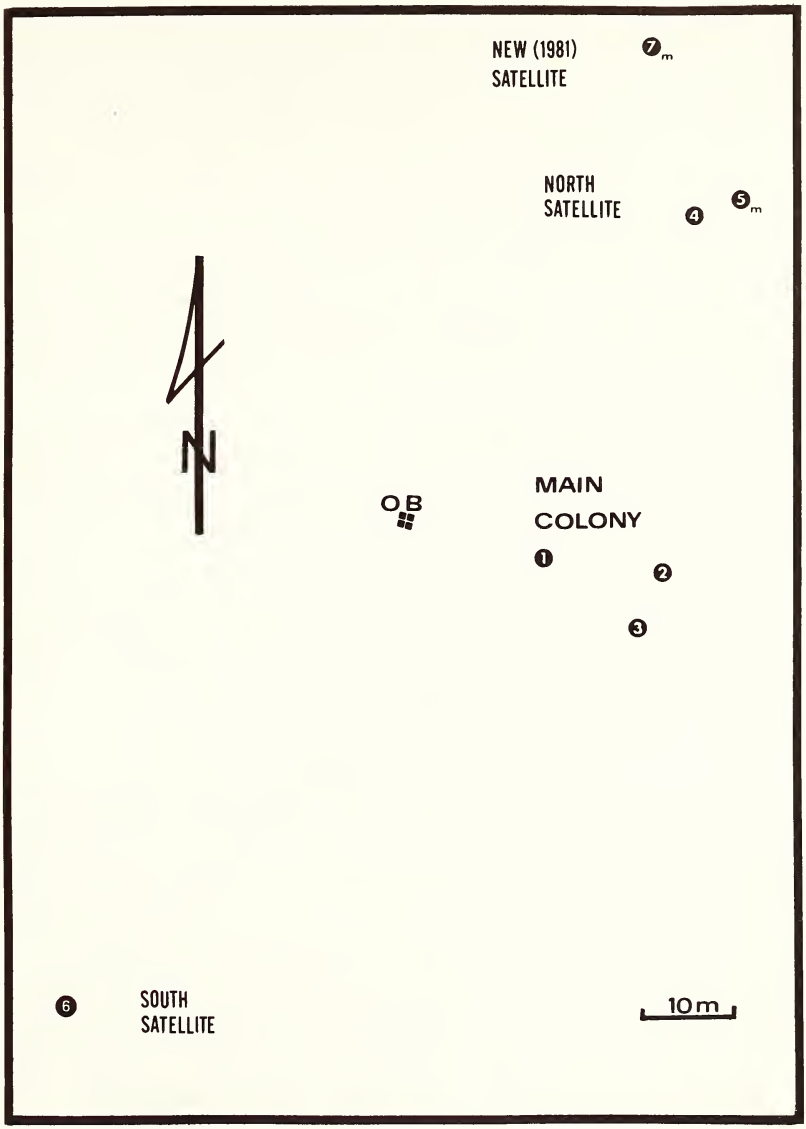

FIGURE 1. *Details of the blue heron rookery. "OB" represents location of observation blind. All nest trees (numbers) are beech except those designated "m" (maple). The southern margin of the woods is approximately 85 m south of "OB".*

The rookery was mapped and nest counts made on February 26, 1981 (Figure 1). The February nest census revealed a main colony comprised of three closely spaced trees containing 41 nests, and two satellite colonies. The south satellite consisted of a single nest and the north satellite colony contained 5 nests in two trees. A post-season nest count conducted on November 19 after leaf-fall yielded 29-32

nests in the main colony and 4 and 9 nests in the two respective satellite colonies. The June 29 helicopter flight revealed a third satellite of one nest in a tree to the north of the main colony. The exact location was mapped during the November 19 ground survey; its position is approximately 18 m northwest of the north satellite. The pre-season and post-season nest counts are summarized in Table 1.

The herons selected the tallest trees in the area (mean height 28.7 m) with nest heights ranging from 19.7 m to 28.2 m. Five of the nest trees were beech (*Fagus grandefolia*) and two were maple (*Acer* sp.)

A blind was constructed 15 m west of the nearest nesting tree and was 14 m above the ground. While this height did not allow observation of nest contents it was sufficiently close so that courtship and nest repair were easily observed and dates established. Activities suggestive of incubation as well as the sounds of newly hatched chicks were also evident from the blind. The blind was also used to observe the behavior of the herons relative to various human impacts.

External observation points were established on county roads 1400N and 600E 1,065 m and 855 m from the main colony respectively. These observation points were used to determine arrival dates and numbers, the directions of flights to and from feeding areas and for additional observations during controlled human impact tests.

Park personnel were also alerted and random sightings throughout the National Lakeshore were recorded.

Two helicopter flights were made over the rookery (May 6 and June 29) to obtain productivity data. Additionally, a fixed-wing flight was conducted on August 20 to verify departure from the rookery and to test the feasibility of using the more economical fixed-wing aircraft for future observations.

Results and Discussion

The HRU heron population is monotypic, consisting only of the great blue heron. The first heron arrived on March 11. Late afternoon counts were made of

TABLE 1 *Summary of Pre-Season (February 26, 1981) and Post-Season (November 19, 1981) Nest Census Surveys**

Main Colony			North Satellite Colony			South Satellite Colony			New Satellite Colony		
Tree	Nest Counts		Tree	Nest Counts		Tree	Nest Counts		Tree	Nest Counts	
	Pre-Season	Post-Season		Pre-Season	Post-Season		Pre-Season	Post-Season		Pre-Season	Post-Season
#1 Beech	15	10	Beech	2	6	Beech	1	4	Maple	0	1
#2 Beech	21	16-19 +	Maple	3	3						
#3 Beech	5	3									
Colony Totals	41	29-32		5	9		1	4		0	1
Rookery Totals		Pre-Season = 47 nests				Post-Season = 43-46 nests					

*See Figure 1 for tree locations.

+ Three very large nests may actually be composed of two adjoining nests. A positive separation cannot be made from the ground. Examination of one of the nests which had fallen during the season was a double nest. The sticks for the two nests had been intertwined but two distinct "nest pockets" were evident.

the herons as they returned to roost until counting could no longer be done accurately. The ultimate population was estimated at 86 to 92 individuals based on the post-season nest census (1). Kushlan (Pers. Comm.) uses this method annually in estimating colonial waterbird populations in the Everglades National Park. A strong correlation ($r = 0.9849$) exists between the increasing number of birds and time. These data show a mean arrival rate of 3.2 birds/day and extrapolation indicates the above population would have been reached by April 10-12 (Figure 2).

The rookery, situated in the tallest trees in a wooded area surrounded by cultivated fields, provides an excellent vantage point for detecting danger. These tall trees, coincidentally, happen to be centrally located within the woods providing additional security for the colony. The relative isolation of the area and the lack of encroachment of housing and industry undoubtedly also contributed to the perpetuation of the colony. Other local rookeries reported to have existed in the area have apparently been deserted.

Courtship was first observed on March 23. Throughout the observation period most of the courtship display described by Cottrille and Cottrille (2) and Mock (3 and 4) were observed.

Pair formation had begun by March 27 and continued rapidly for the next several days. During this pairing-off period extensive nest repairs were conducted; sticks were brought in from outside the colony or "stolen" from nearby nests. Twig stealing was common and any unoccupied nest was vulnerable. Repair of nests was continuous as they were frequently damaged by high winds. Six nests fell to the ground during particularly violent storms.

The first evidence of incubation was obtained on April 3 when a heron was observed rising from its nest and proceeding to poke about in the nest as if rolling an egg. This probing action was repeated with increasing regularity as the season progressed. Egg laying may have started on an earlier date with incubation delayed until the clutch was complete.

The sounds of young herons and the presence of egg shell fragments under the nests indicated that the initial hatching had occurred by May 3. Hatching was confirmed during the May 6 helicopter flight when it was observed that all eggs in two nests had hatched. From this date on, shell fragments were commonly found under the nesting trees.

Both Bent (5) and Palmer (6) report on average incubation period of about 28 days. Pratt (7) reports incubation periods ranging from 25 to 29 days. Assuming incubation did, in fact, begin on April 3 and that the first hatch occurred on or before May 3 the incubation period can be calculated as no longer than 29 days. This is consistent with the 28 day average listed in the above reports.

A juvenile bird, possible from the HRU was observed some 13 km west of rookery on July 2. Following this sighting the number of juveniles observed throughout the National Lakeshore increased markedly.

Although the July 2 observation does not in itself prove first fledging (the bird may have been a wanderer from some distant colony), an early July fledging is supported by data from several other sources. First, this date is consistant with the Graber et. al. (8) observation in northern Illinois. Second, the June 29 helicopter flight revealed that most of the young were in full juvenile plumage and moving actively about the rookery trees. And finally, Palmer (6) lists 60 days as a reasonable time between hatching and fledging; a May 3 hatching would, therefore, give rise to a fledging date of July 2.

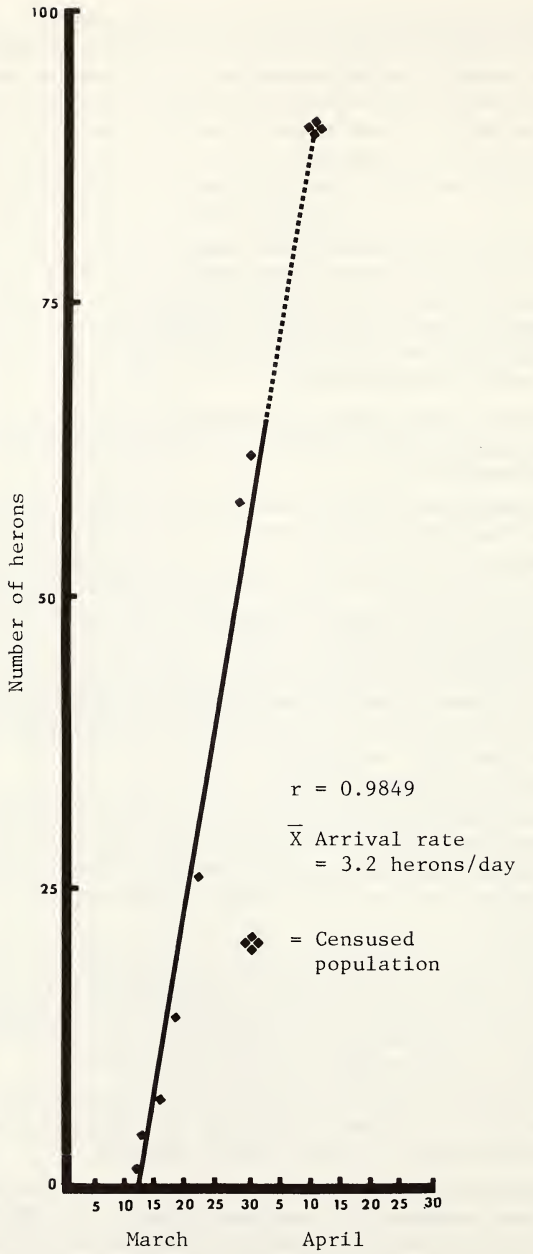

FIGURE 2. *Maximum known great blue heron populations of the Indiana Dunes National Lakeshore heron rookery for seven census dates between March 11 and March 31, 1981. Broken line equals extrapolations of the data.*

A number of additional observations closely support July as the month of fledging for the HRU birds. On July 23, 1981 at least three herons, positively identified as juveniles, were seen in the Cowles Bog Wetland area. A week later eight juveniles appeared in a flooded golf course at Gleason Park (Gary) suggesting a region wide post-nesting dispersal had commenced. On July 28, 1980 Bull (9) reported an unprecedented assemblage of at least 150 great blue herons in ponds near the Cowles Bog area, further documenting a late July post-nesting dispersal. Although it is tempting to assume that all of these late July birds were from the HRU, this assumption is unjustified.

Compelling evidence that young birds disperse widely after fledging exists. For example, a color tagged bird observed at Long Lake (West Beach Unit of the National Lakeshore) August 25, 1977 was, according to the Ohio Cooperative Wildlife Research Unit, "Banded as a nestling in a rookery at the Winous Point Shoot Club on Sandusky Bay, Ohio on May 28, 1977."

Following dispersal the herons did not return to the rookery which was completely vacated by August 7. Occasional herons were noted within the National Lakeshore as late as November 30.

The use of helicopter flights over the rookery yielded critical productivity data through the analysis of aerial photographs. A post-season fixed-wing flight made to test its usefulness for data collection proved to be unsatisfactory due to excessive air speed and lack of maneuverability. Kushlan (10) also found fixed-wing aircraft impractical for observing birds nesting in the crowns of trees.

Analyses of photographs taken during the May 6 helicopter flight showed that of 40 visible nests 37 contained five eggs each, 1 had six eggs and 2 contained chicks. The average clutch size was 5.0 eggs. Employing the method of McAloney (11) in considering any young heron living more than 45 days as "fledged", the 108 juveniles observed on June 29 hatched from 35 active nests (eliminating one nest containing chicks and two nests with incubating adults), give a mean of 3.1 birds per nest. This success rate is in excellent agreement with the 3.09 birds per nest obtained by McAloney (11) in Nova Scotia and is consideraby higher than that reported by others. Graber et. al. (8) reported a production of 1.7 birds per nest in northern Illinois, Pratt (7) reported 1.5 and 1.7 birds per nest for 1967 and 1968 respectively in central California and Wilburn (12) found a production of 2.63 and 2.26 birds per nest for 1970 and 1971 respectively in northern California. Allowing for the known loss of five young birds late in the season the total production of the colony would have been a minimum of 113 juveniles from the 38 active nests observed during the June 29 flight. If, according to Owen (13), a 71% mortality of great blue herons occurs in the first year, then one could predict that 32 birds will survive to return next year. This provides a minimum replacement of 0.71 herons per breeding pair for the year.

Shell fragments with evidence of yolk, were occasionally found under the nests usually following periods of high winds. On May 25 a fully developed, but unhatched chick was found beneath the nest tree. On May 16 a nestling was found below the nests. This young heron apparently choked on a fish (a portion of a fish was protruding from its mouth) and was then removed from the nest by the adults. The partially devoured remains of the five juveniles were discovered beneath the rookery during the first week of August. These deaths occurred over a 4 day period after most of the herons had departed the rookery. A similar pattern was evident in each case; a single pile of highly localized feathers was observed beneath the nesting trees, suggesting that each bird died in the tree and fell to the ground

where it was devoured. Although the deaths of these birds may have been the result of predators, it is also possible that they were abandoned by the adults and starved to death. These birds were likely the result of late nesting attempts and, due to the lateness of the season, were abandoned when the adults dispersed from the rookery with the rest of the flock.

A strong indicator of feeding areas is given by the flight direction of birds arriving and departing the rookery. Of the 1,220 observations of herons flying to and from the rookery, over 56% were in the northwestern quadrant (Figure 3). Supportive of this were the many sightings of herons in isolated ponds in the Cowles Bog Wetland area and along the Lake Michigan shoreline north and west of the rookery. While the Little Calumet River very likely acts as a "leading line", which ultimately takes the herons westward very near the Cowles Bog Wetland; numerous sightings were made of birds flying over open areas on direct flight lines to or from the rookery. The other active flight direction was to the east (16%). On June 17 a freshly bulldozed area adjacent to Round Lake (ESE of the rookery) was found to be literally covered with heron tracks. Round Lake is only one of several ponds and lakes in the area around the HRU. The fact that Round Lake had a field which had been freshly bulldozed made it a good indicator of heron activity in the area. While none of the other small ponds and lakes had freshly turned soil conducive to tracks it is logical that they also are utilized by the great blue herons for feeding. These ponds along with the numerous small streams in the area would account for the other flights to and from the HRU as shown in Figure 3.

The presence of alewives (*Alosa pseudoharengus*), recovered from the beneath the Main Colony on May 16 and June 26, provides conclusive proof that the herons feed in Lake Michigan and their relative abundance (seven of the eight food

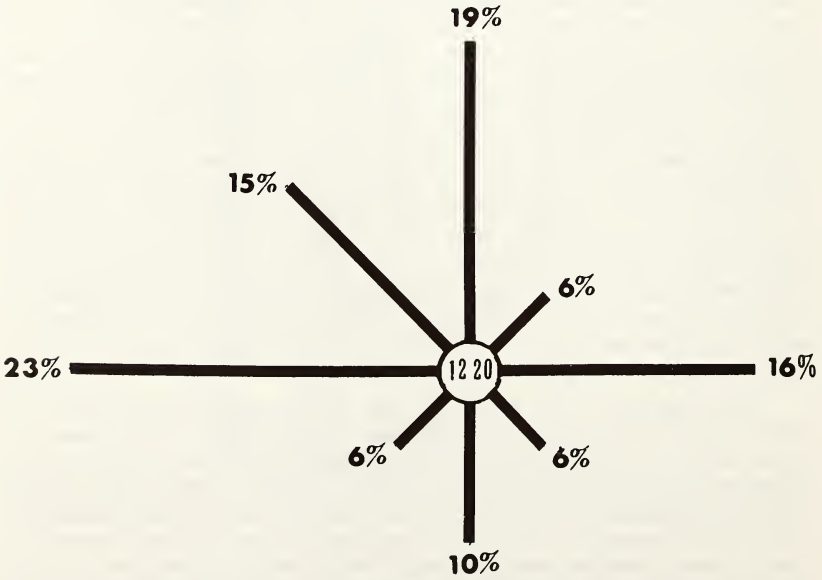

FIGURE 3. *Great blue heron flights, by direction and percent of total (1,220), to and from the rookery during the 1981 breeding season.*

items recovered on the two dates) coupled with the high percentage of flights toward the lakefront suggests that Lake Michigan is the primary feeding area for the HRU birds. Additionally, the coincidence of alewife movement into the shallow waters of southern Lake Michigan with the heron nesting season (R. Koch, IDNR, Pers. Comm.) provides an abundant food supply for the HRU birds during the critical period of their life cycle.

Several researchers have established that the great blue heron diet consists primarily of small non-game fishes (see for example Palmer, 6) and that a critical factor in the maintenance of any heron rookery is amply foraging areas. That great blue herons range far afield in search of food has been noted by several investigators. Mosely (14) indicates that half of the Sandusky County Rookery's total food intake was probably obtained at least 22.4 km from the rookery. Additionally, Krebs (15) shows primary feeding areas located more than 16 km from the British Columbia Colony he studied and Kushlan (Pers. Comm.) indicates that 24 km is a very reasonable distance for foraging flights. The HRU is located 7 km from the Lake Michigan, consequently a flight radius of only 16 km from the rookery would place 29 km of shoreline within range. Also within a circle of 16 km from the HRU is the Cowles Bog Wetland, plus scores of small lakes, ponds and streams.

A tacit assumption involved in the collection of field data on the HRU feeding areas was that all birds within 16 km of the rookery constituted HRU birds. Although great blue herons undoubtedly nest along the Kankakee River (40 km away at its nearest point) a literature search and consultation with local observers revealed the presence of no other active great blue heron rookeries in the Chicago Area of Illinois; northern Lake, Porter and LaPorte Counties, Indiana; and Berrien County, Michigan. Therefore, it is doubtful that any great blue herons from any adjacent colonies fed in the HRU study area. A few of the herons noted in the area may have been nonbreeding wanderers; however, we feel that most of the observations represent feeding HRU birds.

During the initial stages of the study, the blind was entered before dawn and exited after the herons left for the day's feeding, usually by 1000 hours—to reduce the possible impact on the colony. Once incubation had commenced, and herons were present throughout the day, they would take flight when anyone approached within their field of vision. The herons would return to the nests only after we were out of their sight. This flight response to our intrusions continually decreased until by mid April it was possible to walk beneath the herons in the south satellite (enroute to the blind); their reaction being one of scrutiny rather than flight.

The herons showed no response to the sounds of our activities in the blind. Movements of people and equipment, loud talking and even loud whistles did not elicit a reaction from the birds. It became obvious that they reacted primarily to visual rather than audible stimuli. Observations of occasional human activities (fishermen) within 175 m of the rookery and deliberate movements of one of the investigators through heavy brush along the Little Calumet River, 150 m from the rookery, while intentionally making excessive noise (breaking dead limbs etc.) had no observable effect on the population. On June 4 a training hike was conducted for the park's seasonal interpreters. Eighteen moderately noisy people hiked within 85 m of the nesting birds; there was no observable impact upon the herons.

Overflight by fixed-wing aircraft that routinely traversed the area also produced no obvious response from the birds. During the May 6 helicopter flight a series of passes were made over the nests at carefully controlled altitudes (Table 2). Only when the helicopter approached to within 18 m of the highest nests did

TABLE 2. *Results of May 6 Helicopter Intrusion Test*

Height above Ground	Height above Nests	Heron Reaction
183m	160m	None
122m	99m	None
91m	69m	None
61m	38m	One bird stood up
46m	23m	50% of the birds took flight
31m	8m	All birds flew

50% of the birds take flight. It was necessary to approach within 8 m of some of the nests before all birds flew.

Farming within 85 m of the colony apparently does not disrupt the nesting herons. Prior to the onset of incubation of the herons were frequently observed standing in the open fields—particularly during periods of high winds. Farmers have noted that as long as they do not stop their equipment they can pass within 20 m of such herons without the birds taking flight. This apparent lack of concern by the herons to various human activities is in agreement with Kushlan (Pers. Comm.) who states that great blue herons readily habituate to repeated activities that pose no direct threat to them.

Management Recommendations

Recreational Use

Results of this study reveal that in 1981 the rookery was active between March 11 and August 7. Graber et. al. (8) detected some annual variations in timing of the nesting cycle of Illinois herons; consequently, if a time buffer is added to accomodate early or late nesting activities, a comprehensive HRU nesting period might extend from March 1 to August 15. Within this time frame steps must be taken to insure the colony's integrity. Although Buckley and Buckley (16) recommend excluding all foot traffic within 1000 ft. (305 m) of any active colonial nesting waterbird site, it appears that, in view of results of the intrusion impact tests, that the south bank of the Little Calumet River (a minimum of 175 m from the rookery) can be safely opened to limited recreational use during the nesting period. All recreational activities should be excluded from the north side of the river in the immediate rookery area between March 2 and August 15.

As a result of this first year study (a second year is planned) a series of recommendations were made to the park managers. Based on these recommendations an interim management policy was formulated for implementation during the next year. This policy will allow fishing by permit and natural history hikes led by park interpreters. All such activities will be confined to the south side of the river and will be correlated with observations of the herons for further verification that there will be no negative impact on them. The rookery proper will remain closed. Future interpretation of the great blue herons is being considered by means of a video tape program.

Feeding Area

The maintenance of suitable feeding areas is essential for survival of the rookery. This study suggests that the primary feeding areas are along the Lake Michigan shoreline and in isolated ponds in the Cowles Bog Wetland area.

Additional data on feeding areas should be obtained in order to adequately protect these critical areas. It should be noted that the sightings of herons feeding along the lakefront were either at very early or late hours when few people frequent the beaches. If the herons dominant foraging activities occur along the beaches, it may prove beneficial (or indeed necessary) to isolate certain stretches of beach (perhaps for only a portion of the day) during the nesting season to provide quiet expanses of beaches for heron feeding.

Future Monitoring

Graber et. al (8) report a serious decline in the Illinois great blue heron population over recent decades. Although the exact causes of the Illinois decline have not been determined, the authors suggest that human activities played a dominant role. In this context it is imperative that the Heron Rookery Unit be monitored closely on a routine basis in order to quickly detect any decline in the colony. The following procedures will provide the necessary data to evaluate the colony's status.

1) Conduct a November-December (after leaf-fall) nest census annually when the nests can be counted accurately from the ground.

2) Perform routine remote observations from the nearby county roads and establish annual arrival and departure dates.

3) Have trained personnel enter the colony weekly (as inconspicuously as possible) to check for problem signs (dead birds or other evidence of disruption) on the rookery floor.

4) Pre-fledging (late June-early July) helicopter flights (for aerial photography) to provide definitive information on nesting success; a critical parameter in the long range health of any rookery.

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Response of Benthic Diatoms to Removal of Macroconsumers

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Introduction

Changes in community structure and varieties of algae may affect higher organisms in aquatic ecosystems. The fact that changes in populations of higher organisms may exert comparable effects on algae populations is less often recognized (1). Evidence from rocky shore systems suggests that local community structure and diversity is directly related to the number of predators in the system and the efficiency with which predators prevent a few species from monopolizing some limiting resource. Experimentally excluding predators capable of preventing such monopolies resulted in reduction in community diversity. (3, 17, 18, 19). Although the importance of macroconsumers in regulation of microalgal biomass and productivity has been demonstrated for soft mud substrates (2, 5, 16), little data exist concerning the effects of macrofauna on algal community structure. Macroconsumer activities of ingestion, excretion, maceration, and bioturbation may all exert a significant effect on microalgal communities (16).

The present study examines the effect of fish (*Fundulus spp.*) and fiddler crabs (*Uca Pugnax*) on the composition of benthic diatom assemblages in salt marsh creek beds, where light is the major limiting factor (21). The objective of this study was to measure the *net* result of complete macroconsumer removal rather than to determine separate importance values for the various macroconsumer activities.

Materials and Methods

The study was carried out in two tidal salt marsh creeks within the Great Sippewissett Salt Marsh on Buzzard's Bay, Massachusetts. The creeks averaged one to two meters in width and were bordered by *Spartina alterniflora*. Substantial numbers of *Fundulus* occur in these creeks at high tide, while *Uca pugnax* is common in the creek beds throughout the day. The algal community consisted primarily of Bacillariophycae (diatoms), Chlorophyceae (greens), and Cyanophyceae (bluegreens) (26).

Two replicate field experiments, carried out on separate creeks, were designed to assess the effect of macrofauna on the benthic diatom community. Exclusion cages measured 0.5 by 1.0 m with a 5 mm square mesh. One cage was placed in each creek during low tide on July 11, 1981. In addition, one of the creeks (Site 1) contained an identical cage which had been in place for one year. Thirty days later, on August 10, sediment samples were taken from both creeks (Site 1 and Site 2) from grazed and ungrazed plots using a hand-held piston corer 2.5 cm in diameter. With only one sampling date for all areas, shifts in species abundance could be compared between treatments (ungazed and grazed plots) without the added variable of seasonal changes. Two sets of three cores 1.0 cm deep and 5.0 ml in volume were extracted at low tide from: Each 30-day cage (30-day ungrazed plot), the year-old cage located only on Site 1 (year-old ungrazed plot), and surrounding open (grazed) areas. Each 3-core pool was stirred vigorously and 1.0 ml of sediment was removed

and preserved in 50 ml of dilute Lugol's solution. This pooling of cores minimized the patchiness characteristic of most benthic communities.

Organic matter was cleared from the specimens using equal volumes of preserved sample and 30% H_2O_2 (2.5 ml of each was usually sufficient). After bubbling ceased 0.1 ml was distributed evenly on a #0 coverslip and dried over low heat. Coverslips were mounted on slides with Hyrax and examined at 1000X using a phase microscope. Replicate slides were made from each of the six pooled core samples. Approximately 600 diatoms in 60 to 70 randomly selected fields were counted and identified per slide. Several taxonomic references were employed (6, 8, 10, 20, 22). Further counting did not significantly alter the proportions of the dominant species in relation to the total diatom counts, a finding also reported by (26, 27). To assess shifts in species composition based on biomass rather than numbers, further counts were made of diatoms with a maximum length of at least 50 μ. Random fields were examined at 600X until 300 of these larger diatoms were counted and identified from each core pool. Size of diatom was also measured as area using a Zeiss videoplan image analyzer.

Sample dilutions, number and area of counted fields, number of diatoms counted and total surface area of each subsample on the coverslip were used to calculate the diatom species in each ml of sediment. The 10 numerically most abundant diatom species, the dominants, were compared between grazed and ungrazed plots with each species abundance calculated as a numerical percent of the total diatoms in the sample. Further comparisons between treatments were made using the Shannon index of general diversity ($\bar{H}$), an evenness index (e) (15), and a similarity index (SIMI) (25). Significant abundance differences between treatments were determined using a one way analysis of variance.

Results

Effect of macroconsumer removal on total diatom community

Grazer removal had a significant effect on diatom density in both creeks. Ungrazed plots had higher numerical abundances than corresponding grazed plots (Figure 1). Abundance increased with the length of time the plot remained ungrazed.

The structure of the diatom community appeared to be similar for all samples. Ten species, out of 151 identified, dominated the benthic diatom community in Site 1 for both grazed and ungrazed plots (Table 1). Dominants were identical at Site 2 but occurred in slightly different proportions; shifts in the proportion of these species between treatments at Site 2 were similar to those at Site 1.

The percent frequency of *Achnanthes hauckiana* was less in the year-old ungrazed plot than in the 30-day ungrazed plot. It is a genus which adheres strongly to the substrate. Consequently, it may be less affected by grazing than are other diatoms (14, 23). The actual density of the species (as opposed to the percent of the community) (Table 1) indicated that no significant change occurred in the abundance of *Achnanthes hauckiana*, although its frequency within the community decreased. Slight increases in abundance and percent frequency of the chain-formers (*Melosira nummuloides* and *Fragilaria construens*) occurred after macroconsumer removal. This colonizing morphology may facilitate ingestion by macrofauna. Once an end is caught, the whole chain may be pulled in like spaghetti. (14). Simultaneously, meiofauna grazing may be inhibited by cumbersome size of the chain formers. The smaller species, *Fragilaria shiloi*, *Navicula diserta*, and *N. cryptocephala*, decreased in both percent frequency and total numbers after macroconsumer removal. An increase in meiofauna numbers was observed inside

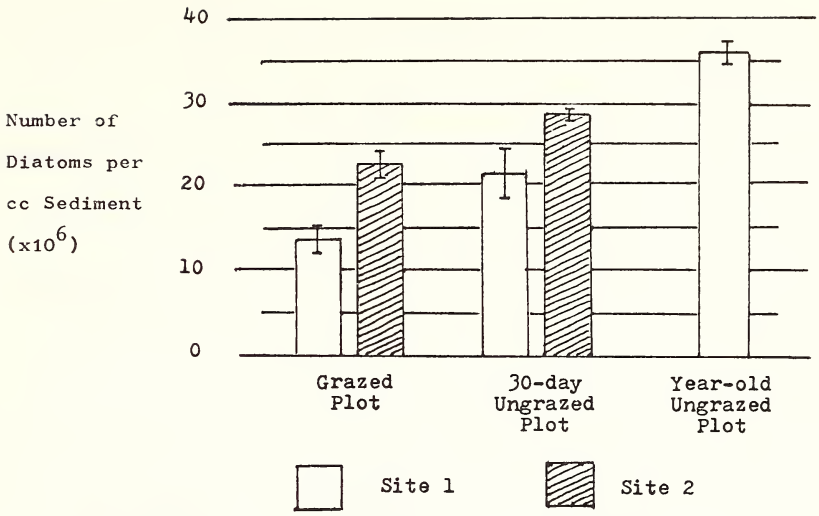

FIGURE 1: *Diatom density ($\bar{x}$ ± SE) in two salt marsh creeks, Site 1 and Site 2, for three different treatments (Site 2 has no year-old ungrazed plot). Samples were taken on August 10, 1981. Differences between treatments (ungrazed nad grazed plots) are significant to the $p < 0.05$ level using a one way ANOVA. Number of diatoms is shown as 10^6 per cc of sediment. Verticle bars above each treatment bar show standard error.*

the cages (pers. obs.). These meiofauna may in turn have been selectively grazing on smaller diatom species. Concomitant increases in the larger species, *Navicula menisculus*, *N. salinarum* and *N. digito-radiata* with macroconsumer removal support this finding. A significant ($p < 0.05$) increase in percent composition and abun-

TABLE 1: *The ten most numerically abundant species and their percent frequency ($\bar{x} \pm SE$) of the total diatom community in Site 1. All samples were taken on August 10. Significant shifts between treatments (* denotes $p < 0.05$) were tested using the one way ANOVA for each species.*

Species	Grazed Plot	30-day Ungrazed Plot	Year-old Ungrazed Plot
Melosira nummuloides	2.72 ± .501	5.62 ± 1.56	3.16 ± .382
Fragilaria construens	30.7 ± 1.44	29.6 ± 1.25	33.7 ± .450
F. shiloi	7.25 ± .092	4.39 ± 1.22	3.07 ± .315
Achanthes haukiana	13.2 ± .944	11.4 ± 1.30	6.56 ± .460
Navicula diserta*	8.19 ± .378	7.02 ± .396	5.29 ± .117
N. cryptocephala	2.61 ± .534	4.94 ± 1.07	2.42 ± .407
N. menisculus	3.62 ± .185	3.15 ± .884	5.92 ± .290
N. salinarum	1.46 ± .120	1.85 ± .442	2.50 ± .070
N. aigito-radiata	.620 ± .120	1.46 ± .357	1.93 ± .251
Amphora no. 152c	2.42 ± .032	4.47 ± .470	1.49 ± .311

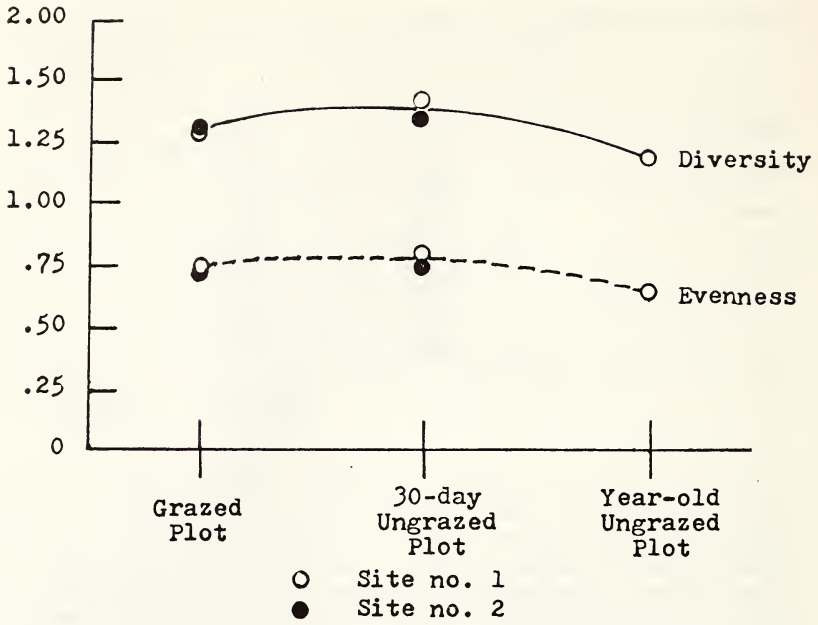

FIGURE 2: *Diversity ($\bar{H}$) and evenness ($\bar{e}$) ($\bar{x}$ ± SE) of the total diatom community at two sites. Differences between treatments are not significant to the $p < 0.10$ level using a one way ANOVA.*

dance occurred in the genus *Amphora* in 30-day ungrazed plots, followed by a sharp decline in the year-old ungrazed plot. The cause of this trend is unknown.

Diversity and evenness indices did not change significantly over a 30-day period in ungrazed plots. However, both indices decreased after one year of macroconsumer removal (Figure 2). Further computations based on the similarity of diatom communities between treatments (Table 2) disclosed slight differences between grazed and 30-day ungrazed, and also between 30-day ungrazed and year-old ungrazed plots, with the largest dissimilarity occurring between the grazed and year-old ungrazed plots.

Effect of macroconsumer removal on population of larger diatoms

A net increase in the abundance and percent frequency of species over 50 μ in length was observed in all ungrazed areas and reached a peak in the 30-day plot

TABLE 2: *Values of similarity between treatments (range 0-1) both for the total diatom community and for populations of diatoms above 50 μ in Site 1.*

Diatom Community	SIMI between Grazed and 30-day Ungrazed	SIMI between 30-day Ungrazed and year-old Ungrazed	SIMI between year-old Ungrazed and Grazed
Total Community	.93	.95	.90
Diatoms above 50 μ	.76	.69	.58

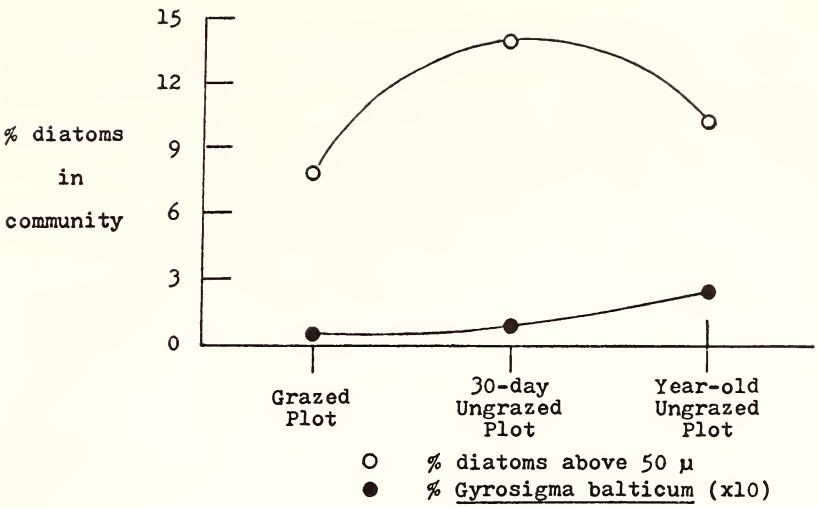

FIGURE 3: *Percent of diatoms larger than 50 μ ($\bar{x}$ ± SE) and percent of one larger dominating species, Gyrosigma balticum, in the total community for Site 1. Concentrations of G. balticum were multiplied by one order of magnitude for comparison. Differences between treatments were significant at $p < 0.10$ level for the concentration of G. balticum but not for the percent of diatoms larger than 50 μ using a one way ANOVA.*

(Figure 3). This result was anticipated and supports previous observations of food partitioning between macrofauna and meiofauna based on diatom cell-size (13, 24). The reason for the peak at 30-days rather than one year is not readily apparent, although it may be due to a more even distribution of certain species. The one-year ungrazed community was heavily dominated by three species. One is *Gyrosigma balticum*, averaging 420 μ in length (Figure 3).

Some significant shifts ($p < 0.05$) in the population structure of these larger diatoms were observed between grazed and ungrazed plots. Because there was no year-old ungrazed plot at Site 2 and there was variability in species composition between sites on other plots, analysis of the populations of large diatoms from Site 2 was not attempted. Table 3 lists the species which occurred most frequently in the three treatments on Site 1. The causes for the changes in percent frequency for particular species did not appear to be size-related. For example, *Gyrosigma peisonis* is half the size of *Pleurosigma angulatum*, but it increased in frequency in ungrazed areas while *P. angulatum* decreased. Similar phenomena occurred with some larger species becoming abundant in ungrazed areas while smaller species decreased in numbers. A trend towards dominance by *Navicula digito-radiata*, *Gyrosigma balticum* and *G. peisonis* was observed at 30 days and reached its maximum in the year-old ungrazed plot where these three species comprised 50% of the large diatoms.

Significant ($p < 0.05$) decreases in diversity and evenness after macroconsumer removal (Table 4) further support the observed trend towards monopolization by a few species. The similarity values obtained for these larger diatoms between treatments (Table 2) indicated substantial differences between grazed,

TABLE 3: *The eleven most numerically abundant species of larger diatoms ($\bar{x}$ ± SE) as percent of the community of species larger than 50 μ in Site 1. Significant shifts between treatments (* denotes $p < 0.05$: ** denotes $p < 0.01$) were tested using the one way ANOVA for each species.*

Species	30-day Ungrazed Grazed Plot	Year-old Plot	Ungrazed Plot
Synedra fasiculata*	2.63 ± .520	8.53 ± .156	4.43 ± .064
Amphiprora no. 29	5.21 ± 1.54	2.83 ± .117	1.35 ± .270
Navicula digito-radiata**	9.84 ± .548	11.1 ± .560	33.1 ± 1.14
Gyrosigma peisonis**	.335 ± .169	.545 ± .130	7.28 ± .580
G. balticum*	.470 ± .283	2.21 ± 1.02	8.49 ± .707
Pleurosigma angulatum	2.48 ± .145	1.66 ± .099	.630 ± .241
P. strigosum	1.43 ± .064	1.02 ± .453	0.00 ± 0.00
Stauroneis sp.	2.86 ± .124	3.02 ± .318	2.11 ± .350
Amphora no. 152*	1.22 ± .325	6.60 ± .438	2.34 ± .633
Amphora sp.**	7.44 ± .435	10.8 ± .131	3.78 ± .396
Nitschia sigma	6.66 ± .912	8.38 ± .527	4.51 ± 1.04

30-day ungrazed, and year-old ungrazed plots. The largest dissimilarity occurred between grazed and year-old ungrazed populations, as would be expected. A simple comparison between similarity values of the total diatom community and the species over 50 μ (Table 2) made clear that the larger species changed most after macroconsumer removal. The total diatom community exhibited some shifts in population structure in ungrazed areas, but the larger species changed markedly.

Effect of macroconsumer removal on size within species

Differences in mean frustule length were observed in some species between treatments. Also, careful measurements indicated a significant increase ($p < 0.01$) in length and surface area of *Gyrosigma balticum* and *Pleurosigma angulatum* after macroconsumer removal in both Site 1 and 2 (Figures 4 and 5). In addition, two other species showed a similar narrowing of the range of size classes and an increase in size through time, possibly indicating that a larger optimal size was being selected for in ungrazed areas.

TABLE 4: *Diversity and evenness calculations ($\bar{x}$ ± SE) for the populations of diatoms larger than 50 μ in Site 1. Shifts between treatments for both diversity and evenness calculations were significant for $p < 0.05$ level using a one way ANOVA.*

	Grazed Plot	30-day Ungrazed Plot	Year-old Ungrazed Plot
Diversity ($\bar{H}$)	1.48 ± .01	1.35 ± .04	1.17 ± .01
Evenness (e)	.87 ± .02	.83 ± .02	.71 ± .01

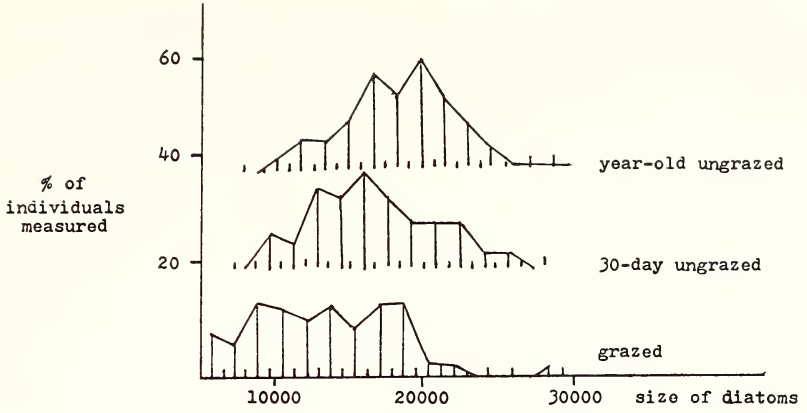

FIGURE 4: *Distribution of size within Gyrosigma balticum for the three treatments in Site 1. Shifts are significant ($p < 0.01$) according to a paired t test. Size of diatom was measured as area on the slide (μ^2).*

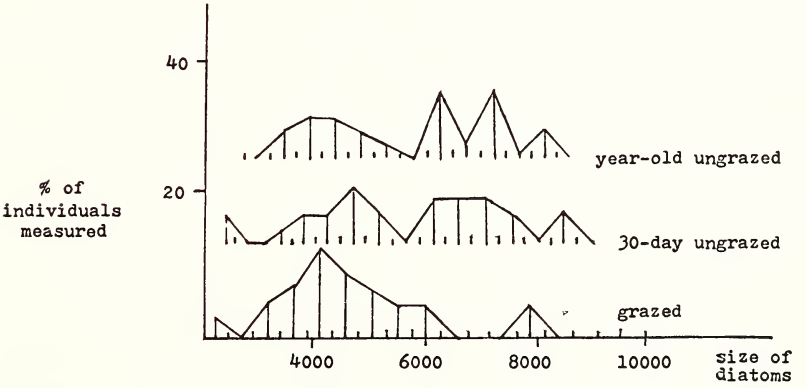

FIGURE 5: *Distribution of sizes (area) within the species Pleurosigma angulatum for the three treatments in Site 1. Shifts are significant ($p < 0.01$) according to a paired test. Size of diatom was measured as area on the slide (μ^2).*

Discussion

Exclusion of macrofauna by cages resulted in significant changes in the structure and abundance of the diatom community. Much controversy surrounds caging experiments, however, and it is important to resolve any errors which might have resulted from experimental design. Effects of shading by cages on the benthic algal community appears to have been negligible, as the tall *Spartina alterniflora* growth bordering the narrow creek banks already shaded the benthic communities. Cages may also act as partial sediment traps by consolidating the creek bottom and allowing algae to grow in denser mats (7) and may cause differences in the structure of the benthic diatom community (25). The absense of bioturbation by macroconsumers could account for these dense algal mats inside cages, although in

an experiment simulating consumer activity, algal productivity appeared to be unchanged (16). In addition to increased algal growth, meiofauna numbers also appeared to be higher in ungazed areas (pers. obs.). Cages may serve as partial refuges from predation, although it is generally accepted that meiofauna are utilized only to a small extent by macrofauna in salt marsh creeks (4, 11, 12). Meiofauna are probably immigrating to these ungrazed areas to take advantage of increased epibenthic algal productivity.

These results indicate that any effects attributable to errors in experimental design are probably minimal or reinforce those caused by macroconsumer removal. Such undesirable stress caused by cages would probably favor certain species, rather than morphological features. Major shifts occurring within the diatom community in this experiment appear to be largely size related and consequently not the result of experimental error. Clearly, macrofauna regulated the populations of larger diatoms, while meiofauna grazed more heavily on smaller species. The extent to which macrofauna ingested the smaller cells is difficult to assess, but past studies indicate that biomass is an equally or more important selective factor than quality of food in the nutrition of many benthic organisms (13, 24). Macrofauna grazing appears then to be a passive type of selection based largely on differences in diatom morphology and accessibility rather than on species—specific picking and choosing (14). Bethic diatoms seem to have evolved to surmount such selective predation by having rapid reproductive rates or by becoming too large to be ingested by most consumers (5, 9). In regards to the effects of grazing on the specific composition of benthic diatom assemblages, Mullin (13) suggests that even a slight preferential removal of certain species could have a considerable effect if maintained for any length of time. Consequently, macroconsumer grazing, however slight, is at a level sufficient to produce considerable shifts in the diatom populations.

Changes in the diatom community after larger grazers were removed closely parallels a procession of events observed by Paine and Vadas (19) in a study on macroscopic algal communities on rocky shores after sea urchin removal; 1.) an immediate increase in abundance and numbers of species present, 2.) establishment of larger "canopy-species", 3.) a succession with the majority of biomass vested in a few species, and 4.) establishment of many smaller species under the "canopy". (The data were not analyzed completely enough to be certain of this last point.) Paine and Vadas' (1969) findings indicate that selective cropping by sea urchins leads to more algal heterogeneity through the reduction of competition. Data on diatom diversity from this experiment leads to a similar conclusion; Macroconsumers may be maintaining diversity by grazing out those species (canopy) which would tend to dominate at the expense of others.

The increase in size observed within several larger species may be attributed to similar competitive interactions in which large size is an advantage both in escaping predation and in maximizing photosynthetic potential in a light-limited system. Similar size shifts within species have been reported by Wimpenny (28) and attributed entirely to grazing pressure. In this study, 30 μ shifts in the mean size of species averaging 420 μ were observed. Most meiofauna ingest diatoms averaging 20-30 μ in length and, consequently, cannot handle such large cells. Competition between species for light in ungrazed areas, which contained up to three times the natural diatom density, may have been a more important factor in controlling intraspecific sizes. This hypothesis is supported by the observed increase in abundance of larger species in ungrazed areas, followed by the eventual dominance of the larger diatom community by several species of *Gyrosigma* and

Navicula, which have well-developed raphe systems thus allowing them to glide upward through the sediment towards light.

Feeding studies show that microalgae are an important food resource for macroconsumers living in the salt marsh (16), but the impact of the consumer on the producer is often neglected. Results from this experiment indicate that the density, community structure, and interspecific interactions of benthic diatoms were significantly affected by the activities of macroconsumers. Size-selective predation by the larger grazers may act further to maintain diversity and reduce competition in the diatom community. Findings from this experiment could have an important impact on future studies of interactions. between different trophic levels in estuarine ecosystems.

Acknowledgments

The experiment was performed and the data collected at Woods Hole Marine Biological Laboratory. I thank John J. Lee for help with taxonomic problems; Phillip Presley and Richard Critz of Zeiss, Inc. for generous instruction and loan of equipment; William W. Dunham for statistical advice; Ann Giblin, John Teal, and Ivan Valiela for instruction in ecology; Paul C. Mac Millan, David Auth, and J. Dan Webster for help with the manuscript.

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Food Habits of the Brindled Madtom, *Noturus minurus* Jordan, and the Redfin Shiner, *Notropis umbratilis* Girard, from West Central Indiana

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Introduction

There is apparently no detailed information available on the food habits of the Brindled Madtom, *Noturus miurus*, or the Redfin Shiner, *Notropis umbratilis*. Thus, stomach and upper intestinal contents from all specimens of this species in the Indiana State University Vertebrate Collection were examined. The purpose of this paper is to present the results of this analysis.

Methods and Materials

Contents of the stomachs and intestines of fish were emptied into water glasses and examined with a zoom dissecting microscope. Identifications were made by comparison with materials collected in the field.

Results and Discussion

A total of 144 Brindled Madtoms was examined, mostly from Otter Creek, Vigo County, 8 mi NE Terre Haute (60 individuals), Brouillettes Creek, Vigo Co., 6 mi NW Terre Haute (45), and from Putnam County (Deer and Limestone Creeks, 35). The remaining fish were from White River at Petersburg, Indiana (Pike Co., 3 individuals), and the Wabash River (Vigo County, 1).

To get some idea of differing food habits by age, the madtoms were separated into two groups, those 40 mm and under standard length, and those over 40 mm. Of the 144 fish examined, only 107 contained food. Fish containing food, followed by the total number examined for each month are as follows. July, 12 of 13 (92.3%); August, 8 of 8 (100.0%); September, 65 of 76 (85.5%); October, 9 of 18 (50.0%); November, 13 of 25 (52.0%); and December, 0 of 4 (0%). There appeared to be much less feeding in winter than in summer.

Data on foods eaten are summarized in Table 1. Main foods of individuals under 40 mm standard length were chironomid and trichopteran larvae and pupae, these four items totalling 82.2% of the food. Small trichopteran cases made up an additional 0.4% of the volume. Chironomid larvae alone comprised about half the total food, and had been eaten by 75% of the fish. A total of nine different items was taken from stomachs. All items identified were aquatic forms, except adult dipterans taken in two stomachs, forming 1.4% of the volume.

Food of the larger individuals was more varied, with a total of 14 items being found. Chironomid and trichopteran larvae and pupae made up a smaller proportion of the food, collectively forming 63.3% of the volume, but small (about 2.5 to 3 mm long) trichopteran houses, with their included larvae, made up 21.6% of the food in the larger fish. It was represented at very low rates in Putnam County and Brouillettes Creek samples, but was abundant in the fish from Otter Creek, forming 33.2% of the food of the larger fish there. Chironomid larvae made up 37.8% of the volume and were found in 82.7% of the fish. Three items, adult Diptera, Cicadellidae, and Cercopidae, were present which were definitely terrestrial, but these formed only 2.1% of the volume.

TABLE 1. *Food of 107 Brindled Madtoms, Noturus miurus, from west central Indiana.*

	Under 40 mm (n = 49)		Over 40 mm (n = 58)	
	% Volume	% Frequency	% Volume	% Frequency
Chironomidae				
Larvae	49.5	75.5	37.8	82.8
Pupae	3.9	4.1	0.7	1.7
Trichoptera				
Larvae	19.6	28.6	18.2	32.8
Pupae	9.3	16.3	6.6	3.4
Small houses	0.4	2.0	21.6	44.8
Unidentified insect	11.4	18.4	7.3	17.2
Ephemerida naiads	4.0	6.1	1.1	1.7
Diptera				
Unidentified adults	1.4	4.1	0.1	1.7
Unidentified larvae	0.5	2.0	3.6	8.6
Cicadellidae	–	–	1.0	1.7
Cercopidae	–	–	1.0	1.7
Elmidae	–	–	0.4	1.7
Culicidae – larvae	–	–	0.3	1.7
Coleoptera				
Unidentified adult	–	–	0.2	1.7
	100.0		99.9	

A total of 213 stomachs of *Notropis umbratilis* was examined, of which 123 contained food. Numbers examined by month (including number and percent with food) were April, 14 (9, 64.3%); July, 110 (87, 79.1%); August, 17 (8, 47.1%); September 56 (18, 32.1%); October, 6 (1, 16.7%); and November, 10 (0, 0%).

It appears that little feeding occurs in winter. It does seem strange, however, that so few fish in September contained food. The overall food of the species is given in Table 2. A great variety of food was eaten, nearly all of it of terrestrial origin.

The most important single foods were ants, Formicidae, at 20.7% and adult midges, Chironomidae, at 19.3% of the total volume of food eaten. Beyond these items, a great variety of foods was eaten, most of it of terrestrial origin and most presumably being gleaned from the surface of the water, as one would expect in view of the superior position of the mouth of this species.

Although sporadic aquatic forms were taken (Corixidae, Emphemerida naiads), early spring, as represented by the April sample, was the only time significant feeding on aquatic forms occurred. At that time, four of the nine fish with food

TABLE 2. *Food of 123 Redfin Shiners, Notropis umbratilis, taken April through November in Vigo County, Indiana. (Adult insects unless otherwise indicated.)*

	% Volume	% Frequency
DIPTERA – Flies		
Chironomidae	19.3	40.7
Chironomidae – pupae	3.1	4.9
Chironomidae – larvae	0.2	0.8
Simuliidae	2.0	2.4
Tipulidae	1.3	2.4
Dolichopodidae	0.4	0.8
Syrphidae	0.4	0.8
Otitidae	0.2	0.8
Sciaridae	0.1	1.6
Unidentified Diptera	13.6	42.3
HYMENOPTERA – Ants and Wasps		
Formicidae	20.7	39.8
Unidentified Hymenoptera	4.2	9.8
COLEOPTERA – Beetles		
Curculionidae	1.2	2.4
Chrysomelidae	0.8	0.8
Elmidae	0.8	0.8
Cucujidae	0.7	0.8
Tenebrionidae	0.5	1.6
Elateridae	0.5	0.8
Cryptophagidae	0.1	0.8
Unidentified Coleoptera	2.8	7.3
Coleoptera – larvae	1.0	2.4
HEMIPTERA		
Corixidae	2.0	2.4
Miridae	0.7	0.8
Lygaeidae	0.4	1.6
Neididae	0.2	0.8
Unidentified Hemiptera	1.3	4.1
HOMOPTERA		
Cicadellidae	2.3	4.9
Aphididae	1.0	3.3
Delphacidae	0.7	1.6
Fulgoridae	0.7	0.8
Membracidae	0.6	0.8
Cercopidae	0.4	0.8
TRICHOPTERA		
Adult	1.0	2.4
Larvae	1.6	1.6
LEPIDOPTERA		
Adult	1.1	2.4
Larvae	2.4	2.4
SIPHONAPTERA	0.6	4.9
THYSANOPTERA	0.9	7.3
EPHEMERIDAE		
Naiad	0.4	0.8
CORRODENTIA		
Psocidae	0.04	0.8
Unidentified Insect	2.9	8.1

TABLE 2.—Continued

ARANEIDA	4.3	5.7
Seeds	0.3	0.8
Feather	0.1	0.8
	99.8	

had fed on chironomid larvae or pupae (44% frequency, 40% of the volume in the April sample).

Both midges and unidentified Diptera often consisted of numbers of tiny flies in individual stomachs. It appeared that these may have been eaten, several at a time, from the surface.

Particularly interesting items found in the stomachs of 6 different fish, were fleas, one per stomach. Three were dog fleas, *Ctenocephalides canis*; one was a mouse flea, *Orchopeas leucopus*; one was a shrew flea, *Ctenophthalmus pseudagyrtes*, and the last was too mutilated to be identified. My guess was that the fleas were from animals which had been dead in the stream.

Foods eaten by smaller sized fish (under 40 mm standard length) (total of 19 individuals with food were examined) were chironomid adults (23.2% volume, 36.8% frequency), unidentified Diptera (22.6%, 31.6%), chironomid pupae (16.1%, 26.3%), ants (10.8%, 21.1%), Hymenoptera (10.5%, 10.5%), Trichoptera larvae, Hemiptera and Simuliidae (each 5.3%, and 5.3%), flea (1.1%, 5.3%).

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ABSTRACTS

HERPIC – County Storm Drainage Manual. CHRISTOPHER B. BURKE, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.——The Highway Extension and Research Project for Indiana Counties (HERPIC) has funded the writing of a drainage manual for the state of Indiana. This manual has been written for practicing engineers and designers who are involved in the design of drainage facilities. The content includes chapters on precipitation, runoff, open channel flow and the design of gutter and inlets, storage facilities, and storm sewers. Each chapter presents a general review of the subject, a discussion of design procedures and required graphs, tables or figures, example problems illustrating applications, and references for further investigation. Three appendices are included to provide the user with auxillary references. The first two appendices review the basics of statistical analysis (as it applies to the analysis of precipitation and runoff) and hydraulics. The third appendix provides a brief listing of regulatory agencies (local, state and federal) which have jurisdiction over drainage projects in Indiana. The manual may be purchased by writing to HERPIC, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.

Anthropometric Data Error Detection and Correction with a Computer. DAVID D. CHESAK, St. Joseph's College, Rensselaer, Indiana 47978.——Data obtained with automated anthropometric data acquisition equipment is subject to short term errors. These errors are due to random reflections of light, masking of the light rays and other types of interference, optical and electrical. These signals are impossible to eliminate from the initial data produced by the television cameras. There is a need to ascertain which data values are erroneous and to replace them with corrected values, if possible. This is primarily a software problem and requires a digital computer to refine the data off line. This paper discusses the use of the least squares method for this purpose.

History and Computer: An Unorthodox Approach to River Hydraulics. ALDO GIORGINI and DEAN RANDALL, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.——When a river bed is very tormented, there may be different flow patterns corresponding to different discharges. As an example, if a river has a low water bed carved in the rock, with very tortuous patterns, when the discharge is high, the low water river bed may be a mere "accident" on the pattern of the high water regime. In this instance it is not sufficient to have only one numerical model for the river (i.e. for the use of HEC2); but one should have at least 2 models, sometimes quite different from each other.

This is illustrated in a very dramatic fashion by the study of the determination of the low ater discharge of the Ohio river across the Louisville Chutes at the time when the Louisville-Portland Canal was not there and and the barges or boats had to brave the Indian Chutes.

PHOTO: A Computer Program for the "Photographic" Rendition of Three-Dimensional Objects. ALDO GIORGINI and MARK SMITH, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.——The photograph-like rendition of simple three-dimensional objects by computer is a problem that has attracted the attention of most computer graphics specialists. The degree of success of the operation depends on several factors among which the most important is the versatility of the color terminal that is used for the rendering. The work described here is taylored to a TEKTRONIX 4027 color terminal. The screen of such terminal has 480 x 640 pixels singularly addressable by only one out of eight colors with invariant beam density. While this provides sufficient ground for what is mis-called "high resolution graphics", it still yields somehow rough images. The color palette has to be extended by software, and this has been done as a preliminary task of the development of PHOTO. In order to prepare an object for representation, two families of curves are drawn on its surface. Each facet so obtained then is projected on a picture plane with the color attributes that depend on: facet color, light source(s) colors, facet surface reflectivity, relative position of source(s), facet, and observation point.

Several examples of color rendition are shown together with the technical problems that had to be overcome.

Performance of Embankments Constructed with Compacted Clays. M. J. GOODMAN and J.L. CHAMEAN, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.——Embankment performance must be evaluated at the end of construction as well as for the long term conditions. The long term conditions are frequently critical because of water saturation occurring with time. The performance criteria are stability with respect to slope failure and settlement and/or swell of the embankment. Slope failure leads to loss of the embankment while settlement or swell results in pavement distress.

The performance criteria are affected by compaction variables such as compactive effort, compactive prestress, dry density of the clay, optimum moisture content, molding water content, and state of saturation. Unfortunately, for typical compactive efforts, manipulation of these variables to optimize either performance criterion may be detrimental to the other.

The STABL2 program developed by Boutrup (1977) is used to evaluate the slope stability of embankments. Settlement and/or swell are evaluated by a computer program developed by the authors. Examples are presented to illustrate the maximization of embankment performance. The analyses are performed using compaction variables for a clay typical of Southern Indiana.

The Effect of Body Shape on the Growth and Structure of Turbulent Wakes. DONALD D. GRAY and GERALD F. SHELDON, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907——Traditional theories of the turbulent far wake predict that the mean velocity field depends only on a few gross parameters such as the free stream velocity and the drag on the body producing the wake. They imply that the wakes of comparable objects, such as a sphere and a circular disk normal to the free stream, are indistinguishable when appropriately normalized. The rationale for this conclusion may be that wake turbulence achieves a universal structure or that differences in the structure of turbulence do not effect the mean flow.

Bevilaqua and Lykoudis [1] compared the wakes of a sphere and a porous disk of equal drag. A near wake recirculation zone was found behind the sphere but did

not form behind the porous disk. In both wakes the mean velocity profiles quickly reached the same self-preserving form, yet the sphere wake spread twice as fast as the disk wake. Behind the sphere, periods of non-turbulent flow were observed on the centerline starting at 20 diameters; but the centerline flow behind the disk remained fully turbulent for more than 100 diameters. Flow visualization revealed that this phenomenon was due to the presence of large eddying bulges in the sphere wake in contrast to the generally smooth disk wake boundry. Bevilaqua and Lykoudis concluded that the rapid spread of the sphere wake was due to the high entrainment efficiency of these eddies and that their formation was related to the shape of the drag producing body.

Castro [2] studied the near wake within 20 chords of long flat strips mounted normal to the flow in a wind tunnel. A series of 11 solid and perforated strips were used which had ratios of open area to total frontal area (porosities) ranging from 0 to 0.645. For porosities of less than 0.3, a recirculation zone formed behind the strips. Considered as functions of porosity, the drag coefficient and eddy shedding frequency dropped abruptly at a porosity of 0.2. Castro concluded that for small porosities the shear layers from the strip edges interact to form a vortex street. At higher porosities the flow through the perforations prevents vortex street formation.

The present experiments emphasized far wake mean velocity measurements behind solid and porous (porosity = 0.425) strips similar to those used by Castro. Velocity profiles were made at 20, 40, 60, 80, and 100 chords behind the strips at a Reynolds number of 25000. It was found that the normalized velocity profiles approached the same self-preserving form beyond 20 chords, yet the normalized growth rate of the solid strip wake was about 40% faster than that of the porous strip wake. This is attributed to the presence of efficiently entraining vortices in the solid strip wake which are not present in the porous strip wake.

Taken together, the studies suggest that the presence of large eddies in far wakes is crucial to the entrainment process and that their formation does depend strongly on the details of the body geometry.

1. *Bevilaqua*, P.M. and P.S. *Lykoudis*, 1978, Turbulence Memory in Self-Preserving Wakes, *Journal of Fluid Mechanics*, Volume 89, pp. 589-606.

2. *Castro*, I.P., 1971, Wake Characteristics of Two-Dimensional Perforated Plates Normal to an Airstream, *Journal of Fluid Mechanics*, Volume 46, pp. 599-609.

How and Where to Find Water. ROBERT H. L. HOWE, West Lafayette, Indiana 47906.——A rapid and economical method has been developed, tested, and used for finding and assessing the availability of ground and surface water in a defined watershed. The method is based on pilot office studies of the geology, land uses, physiology, soils, vegetation, topography, climatic data, and other pertinent hydrological elements by aerial photographic (low altitude and high altitude photos, infrared and color photos, etc.) information and technique of recognition, of the selected pilot area.

Equations are derived and tested on field studies in areas similar to pilot models. The reliability of this method by remote collection of information is further verified by actual ground surveys and physical comparison. A water resource inventory can be produced for an area where limited hydrological data are available. A computerized model and system can thus be produced for different areas. Results are used for satellite surveys verification.

The technique developed for finding ground and surface potential and

availability in relation to industrial development, urban water supply, agricultural demand, hydroelectric power estimation, pollution control, hydraulic model construction, etc., is illustrated by a color movie. Appreciation is acknowledged hereby to Dr. Robert Calwell of NASA and the University of California, co-investigator and project co-advisor of the author, and also to Dr. Shirley Griffith, Special Assistant to the President of the United States where the project was undertaken.

Reservoir Optimal Operating Rules Generated by Stochastic Optimization. MOHAMMAD KARAMOUZ and MARK H. HOUCK, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.——This study considers a stochastic optimization model to determine general operating rules for a given single reservoir system. The optimization model is a stochastic dynamic program which requires a discrete, lag-one Markov process as the streamflow descriptor. This optimization technique produces a set of optimal operating rules which can be tested by simulation of actual reservoir operation.

The Markov process which is assumed to describe the streamflows is based on the probabilities of transitioning to an inflow in season t + 1, conditioned on the inflow for season t. A set of characteristic storage volumes and streamflow are chosen so that the entire range of storage volumes and streamflows are considered. The operating policy designated by this model is a set of rules specifying the storage levels at the beginning of the next season for each combination of storage levels at the beginning of this season and inflow during the season.

The stochastic optimization model was successfully developed and tested for annual and monthly time periods for the Gunpowder River, Maryland, the Osage River, Missouri and the Blacksmith River, Utah. The reservoir capacity, number of discrete storage levels, and number of inflow intervals were varied to determine the best state increment. A complete description of the algorithm and test results is given in the paper.

Computer-aided Analysis of Radar Data for Forest Cover Mapping. DOUGLAS J. KNOWLTON and ROGER M. HOFFER, Department of Forestry and Natural Resources & LARS, Purdue University, West Lafayette, Indiana 47906.——Tremendous progress has been made over the past decade in demonstrating the potentials and limitations for applying computer-aided analysis techniques to multispectral scanner data obtained in the optical portion of the electromagnetic spectrum. Such techniques are being utilized operationally to identify and map various earth surface features, such as forest cover types, water bodies, geologic features, agricultural crops, and others. With the continual interest in and development of sensors that obtain data at wavelengths beyond the optical portion of the spectrum, (i.e., Synthetic Aperture Radar [SAR] systems) additional data sources are becoming available.

Dual-polarized, X-band SAR imagery was obtained from an altitude of 60,000 feet over a test area near Camden, South Carolina on June 30, 1980. The imagery was digitized so that computer-aided analysis could be performed. However, before the classification algorithms could be used, the SAR data had to undergo various preprocessing techniques.

One of the preprocessing requirements was to overlay the two different polarizations so that they shared common line and column coordinates. A simple linear or biquadratic fit was to be used to overlay the data, but the geometric characteristics of the data proved to be much more complex than anticipated. The first portion of this paper describes the steps which had to be followed in order to

successfully overlay the digitized dual-polarized radar data. The second portion describes the results obtained from the computer classification of the overlayed radar data.

The results from this work in overlaying and classifying the SAR data provided important insights into some of the characteristics of the data itself. The steps between the collection and classification of the data can appear to be straight forward; however, they may turn out to be very complex. New data sources, such as SAR, are important and can lead to very interesting and useful applications, but one must also be aware that the use of digitized dual-polarized SAR data has some distinct limitations, and special preprocessing procedures will be required in order to effectively utilize quantitative data processing techniques.

HECSECT: A Computer Program for the Graphical Representation of River Cross Sections. H. R. LEMMER and ALDO GIORGINI, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.——A major difficulty with computer analysis is to ensure the accuracy and correctness of the large amount of input data required. As the complexity of the program increases the less likely it becomes that errors in the input data can be easily detected in the output.

Graphical representation of data is a very useful tool in comprehending and understanding large sets of numbers. This program HECSECT was therefore developed to enable the user of HEC2 to check the accuracy of the cross-sectional data required by the program.

One additional control card must be added to the cross-sectional data required by HEC2 in order to obtain CALCOMP or VERSATEC drawings of the cross-sections as they are to be used by HEC2. Various options are also added to the program to cater to the various needs that the user might have.

Although the program was developed for use with HEC2, it can also be used to plot cross-sections in areas other than river cross-sections.

The program was developed for a project in river hydraulics and has been very useful in pointing out errors in the data, that had previously gone undetected.

A specially useful application of the tool consists in the comparison of data taken in different surveys. The river channel modification can be perceived at a glance.

Specification of Fill Compaction. C. W. LOVELL, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.——The specification of fill compaction has a single objective, viz., to produce a structure of compacted material of *predictable* performance. Such performance is predictable through appropriate controls over: (a) the material used, (b) the compaction process employed, and (c) the end result produced. Performance to be predicted may include drainage, lateral pressure, settlement and shear strength. Parties to the specification include the owner, engineer, constructor, and construction manager, and all want to avoid the situations of (a) no specification, (b) incorrect specification, (c) arbitrary specification, and (d) excessive specification, since any of these either fails to produce predictable performance or wastes resources.

Proper specifications are developed via previous experience, test fills, or laboratory testing. Unfortunately, the specification can seldom be based directly upon the material properties which must be predicted, because these are too difficult to directly measure in the field. Rather, the desired performance properties are related to simple measures such as, (a) density, relative density, relative com-

paction; (b) water content or degree of saturation; and (c) penetration resistance or proof rolling.

Examples of proper specification are given.

SURZUNI: A Computer Laboratory for Numerical Experiments with Liquid Motion in the Presence of Surface Tension. MARK SMITH and ALDO GIORGINI, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.——The program ZUNI, developed by the Los Alamos Laboratories of the University of California, has been known for some time as one of the most versatile computer laboratories for numerical experiments on fluid flows with free surfaces. The program is general enough to include both two dimensional problems expressible in terms of Cartesian coordinates and two dimensional problems expressible in terms of cylindrical coordinates. Either ideal fluid or viscous fluids can be simulated by the program and the "test section", the region within which the fluid motion takes place, is a rectangular region for Cartesian coordinates and a cylinder for cylindrical coordinates. Furthermore, fluid can enter and leave the test section through openings at the boundaries.

The limitation of the ZUNI Program is constituted by the fact that no surface tension provision is made. This limitation excludes from consideration all those fluid motions where surface tension is an important parameter, like drop and bubble vibration, drop and bubble collapse, etc. . .

The program SURZUNI has been developed with this category of problems in mind. The modifications to the original program are of considerable finesse. The first difficulty to overcome was the accurate determination of the curvature of the free surface for a grid size that would make the numerical calculations feasible in a reasonable amount of time; then the problems related to the merging of two surfaces when two liquid bodies approach each other, before coalescing, and the problem of the splitting of one liquid body into two. These problems have been resolved very successfully as the several numerical experiments describing different hydromechanic problems illustrate.

Wide use is made of computer graphical techniques.

Multiobjective Approach for Energy Planning and Allocation. T. TREZOS and A. RAVINDRAN, School of Industrial Engineering, Purdue University, West Lafayette, Indiana 47907.——The problem of energy planning and allocation is approached through the use of multiobjective optimization. Two models are developed in this study. The first one makes use of the goal programming concepts and optimizes certain objectives according to their priorities in a sequential procedure. The second one derives the trade-off between any two objectives (bicriterion problem), using the Non-Inferior Set Estimation algorithm. The developed models take into consideration any constraint on the energy consumption (energy shortage), all the available forms of energy resources, new technologies of energy production, as well as the increase of energy prices and the reduction of the unemployment rate with respect to the level of the energy consumption. The models are illustrated using energy data for the State of Indiana. Energy data related to the State were collected from various sources for the model applications. Through these applications, the models are shown to be a useful tool to assess the impact of future energy shortage, higher fuel prices, introduction of newer technologies, and various allocation policies.

Virtual Instrumentation: Microcomputers at Work in the Laboratory. DAVID R. VOLTMER and ROGER N. GALLION, Department of Electrical Engineering, Rose-

Hulman Institute of Technology, Terre Haute, Indiana 47803.——The development of a new instrumentation concept, virtual instrumentation, holds the promise of versatile, cost-effective instruments for undergraduate laboratories. Virtual instrumentation exploits the increasing cost-effectiveness of digital technology through an approach which designs around a microcomputer, emphasizes digital system techniques, and uses self-contained software to operate the instrument. The microcomputer under the control of user-selected software electronically configures the hardware and processes the data to perform the desired measurement.

The user, following instructions displayed on a CRT screen, controls the virtual instrumentation via the microcomputer keyboard. In response to user commands, test signals are generated as digital numbers which are converted to analog form for application to the circuit under study. The response signals from this circuit are detected and converted to a sequence of digital numbers. Sofware algorithms process these numbers according to the selected instrument functions and presentation format. The results are displayed to the user.

The encouraging results of the prototype system feature increased capability, versatility and cost-effectiveness. With increased development efforts and technological advances, the future of virtual instrumentation is bright.

The Indiana-Kentucky Boundary Dispute: An Unorthodox Approach to River Hydraulics

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Introduction

The two century old boundary dispute between Kentucky and Indiana has been recently settled out of court. Exception made for few locations, the 354-mile border will be at least 100 feet south of the north shore of the Ohio River, and as much as 300 feet at some points. The detailed point by point polygonal will be definitely fixed by experts under the supervision of both parties in the dispute.

The first question that comes to one's mind at this point is whether the boundary between the two states was even fixed in the past and became uncertain (for any number of reasons) with the passing of time, or it was never accurately fixed, thereby creating a *de facto* no-man land between the two states. A sketchy answer to these questions will be outlined in the following paragraphs, with the purpose of giving the background for the complete understanding of the contribution of the computational hydraulic phase to the solution of boundary dispute.

Before the Revolution, Kentucky County was the westernmost settlement of the English Colony of Virginia. What was going to be the Northwest Territory *lying north of the Ohio River*, (comprising what eventually became the States of Ohio, Indiana, Illinois, Michigan, Wisconsin, and Minnesota) was still regarded by the young State of Virginia as its domain. Both the Kentucky County and the Northwest Territory were protected against terrorist action of British soldiers, pro-British American Loyalists (Tories) and allied Indians by guerrilla counteraction as the one led by the young Virginia surveyor George Rogers Clark, under commission of Virginia Governor Patrick Henry (7).

At the end of the George Rogers Clark's feats, in 1779, the Virginia Legislature elevated the Virginia County of Kentucky to the status of the Province of Kentucky and it declared the *country north of the Ohio River* to be the new Virginia County of Illinois. Elections were held the same year and Virginia could claim to be functioning as the State government throughout the territory north of the Ohio River all the way to the Canadian border.

The continuous efforts to defend the lands of the Midwest had improverished Virginia to the point that it was alleged that the State was planning to sell directly to individual settlers all of its claims north of the Ohio River. On September 6, 1780 Congress passed a resolution calling on all the States for "a liberal surrender of portion of their territorial claims, since they cannot be preserved entire without endangering the stability of the general confederacy . . ." and, on October 10, demanded that those lands "be settled and formed into distinct republican states, which shall become members of the federal union and have the same rights of sovereignity, freedom and independence, as the other states."

On March 1, 1784, with the first land cession, Virginia released "all right, title and claim . . . to the territory *northwest of the river Ohio*."

On June 1st, 1792, when the State of Kentucky was created, its northern boundary was declared to be "the north bank of the river Ohio at low water mark".

When Indiana was admitted into the Union as its 19th member, on December

11, 1816, the boundary between Indiana and Kentucky was therefore the north bank of the Ohio River as it was, at low waters, in 1792.

While during the nineteenth century no serious disputes arose about the boundary between Kentucky and the trans-ohian states of Illinois, Indiana and Ohio, the nineteenth century has seen several disputes brought to the United States Supreme Court, which consistently dodged the boundary question. A brief listing of the Court's actions follows:

1966—The State of Ohio files an original action in the United States Supreme Court, asserting that the boundary between Ohio and Kentucky is the 1792 low-water mark.

1971—The State of Ohio tries to amend its 1966 Complaint in the Supreme Court, arguing that the boundary should be the middle of the river.

1973—The Supreme court dismisses the case sustaining that Ohio should have raised its "middle of the river" argument when it became a state in 1803.

1980—The Supreme Court, by a vote of 6 to 3, upholds Ohio's position that *the boundary was forever fixed at the 1792 low-water mark*, against the Kentucky contention that the boundary between the three states and Kentucky was not fixed forever at the 1792 low-water mark. Soon after the *Ohio v. Kentucky* decision was made, Indiana's Attorney General, Theodore L. Sendak, asked the Supreme Court to make the same ruling in *Kentucky v. Indiana*, which the Supreme Court granted on March 24, 1980.

This date is the end of the dispute about the *definition* of the boundary between Indiana and Kentucky: *the boundary is the 1792 low-water mark.*

What was left was its *determination.* This task was not a straight-forward one, since rivers do change their course in time, and since there are neither accurate 1792 maps of the Ohio river nor hydrologic data that give the value of the 1792 low-water surface elevation. The task could actually be one of gigantic proportions, with involvements of land surveyors, geologists, hydrologists, river hydraulics experts, etc . . . if it were necessary to litigate one by one the 354 miles of the boundary. This was, in fact, not done. Only key locations were subjected to extensive research. One of these locations, which is the object of this report, extends from McAlpine Dam in Louisville, located where once were the Chutes, and Six-mile Island, near Utica, six miles upstream of the Chutes, where the third State-owned port in Indiana, the Clark Maritime Center, is planned to be built.

This paper presents the comutational hydraulic phase of the research project on the Chutes-Six-mile Island reach of the Ohio River.

Formulation of the Problem

The problem can be formulated in rather simple terms: *given the bathymetry of the Ohio River reach that starts at the Louisville Chutes and ends at Six-mile Island, and given the low-water elevations of the reach, find the north shore.*

As such the problem is a characteristically geometrical problem whose solution is exclusively within the province of the land surveying discipline. What makes the problem a wider scope problem involving other disciplines is the fact that what should be given is actually not known, and has to be found or estimated by those other disciplines.

The data of the problem are: the bathymetry of the reach under study as it was at the time of low waters in 1792, and the low-water elevations of the same

reach, at the same time. The finding of these data is the object of other discipline's problems.

As for the 1792 bathymetry, since no records prior to those collected during the survey of 1911-1914 have the accuracy required for the determination of the boundary, the problem can be cast in the following terms: is it possible to infer the 1792 bathymetry from the maps printed by the Army Corps of Engineering, following the 1911-14 survey of the Ohio river? This can obviously be done if the river has not changed in the time span 1792-1911 or if its movements can be traced accurately. Geological evidence (10) points at the very stable nature of the northern shore of the Ohio river, especially around Six-mile Island where "the sum of the geological evidence suggests that the Ohio river has not been displaced north or west of the present position in historic time, nor probably even earlier". Graphical comparison of the cross-sections of the river as obtained from the 1911-14 survey and from the 1964 survey has confirmed the geological findings by showing that only minor changes have occurred in the Ohio River reach under consideration in the past 50 years, and that these, due mainly to the effect of the building of McAlpine Dam, are not affecting the northern shore near Six-mile Island (2).

The problem of the 1792 low-water mark is actually much more complex. In lack of any numerical data of that time, and since low-water marks do change from year to year, one must obviously relinquish the thought of finding the true low water elevation in 1792 and accept the concept of "probable" low water elevation in 1792. It is here that history, hydrology, and computational hydraulics fuse together to yield alternate answers with different probability attributes. Historical accounts point at the fact that several times the Ohio Chutes of Louisville had so little water that herds of buffalo were crossing the river (8). Furthermore some correspondence between Major General Henry Knox, Secretary of War, and Major General Anthony Wayne (9) which was kindly brought to the authors' attention by William Krisle, suggests that during the summer of 1792 the Ohio River was flowing as a mere trickle down the Chutes, and was probably dry in several reaches. This account of the discharge conditions points at an elevation of the water surface in the pool stretching from the Chutes to Six-mile Island of roughly 400.7 feet above the mean sea level. The effects of this pool level on Six-mile Island are shown in Figure 1-a (3).

As for the hydrological counterpart of the historically based 400.7 foot pool elevation, it has been found that the lowest recorded stage since the year 1858 occurred in the years 1881 and 1895 and was 404.7 feet (10). The average return period of such stage or lower has been shown to be 20-30 years. Albeit the probability of the low-water stage in the pool under consideration being equal to or lower than 404.7 in any given year is only 3-5%, the historical findings mentioned above indicate that the low-water mark of 1792 might have been a still rarer occurrence.

Furthermore the 404.7 stage was measured when the river had manmade structures that were increasing the pool level. The effects of a 404.7 pool level on Six-mile Island are shown in Figure 1-c.

The Hydraulic Problem

The computational hydraulics phase of the search for the 1792 low-water mark has its inception with the realization that the low water mark of 404.7 feet, obtained from a survey conducted that year, and reported on a 1903 map, has acquired the status of *standard* low water mark for the maps that were issued after the 1911-14

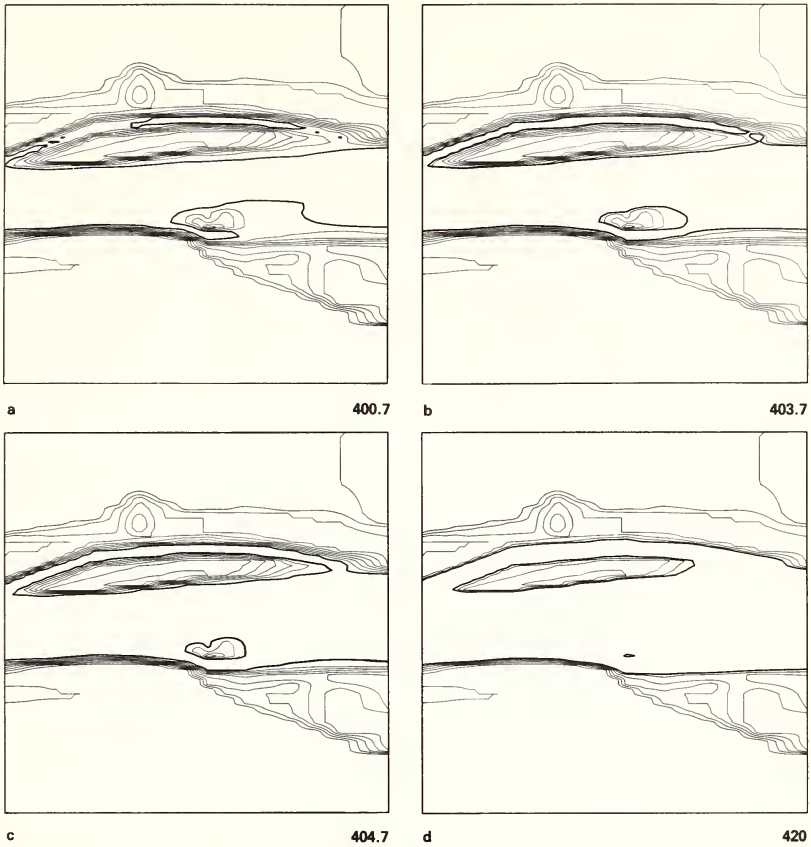

FIGURE 1. *Shoreline configuration near Sixmile Island: a. at stage 400.7 ft, when the Louisville Chutes were dry; b. at stage 403.7 ft, this paper's upper estimate for the 1792 low water mark; c. at stage 404.7 ft, low water mark of 1895 when a wing dam was present; d. at stage 420, ft, nowadays normal pool level, after the construction of McAlpine Dam.*

survey and after the 1964 survey. The realization that such low water mark was measured when a wing-dam was lying across the Middle Chute, with the purpose of conveying the discharge of the river through the Indian Chute (see Figures 2 and 3) in order to facilitate navigation, suggested that the 409.7 foot low-water mark was corresponding to a discharge which would have yielded a still lower low-water mark, had the wing-dam not been there, that is, had the Chutes condition been natural, as they were in 1792. The hydraulic problem was therefore clearly formulated: given the pool elevation of 404.7 feet and the wing-dam on the Chutes, find the corresponding discharge to the discharge just found, which should be lower than 404.7 feet.

The first phase of the problem solution was the study of geometric characteristics of the river bed. The entire reach from the Chutes to Itaca, as recorded in 1911-14 survey and the 1964 survey, was digitized section by section (1),

FIGURE 2. *Map of the Ohio Chutes as drawn in 1843 by Capt. Cram, presenting the 1809 low water conditions.*

the data of the two surveys were compared (2), and the two numerical models so obtained were formatted for use in the HEC2 program (6), a FORTRAN program developed by the Army Corps of Engineers for the calculation of water surface profiles in rivers. The numerical model resulting from the data of the 1964 survey were used to check whether the HEC2 program was yielding results comparable to measured elevations at different discharges (3). Upon satisfactory conclusion of the comparison, and upon definite verification of the fact that, from a hydraulic viewpoint, the reach under consideration (see Figure 5) behaves like a pool for low and intermediate discharges, the direction of the research was clearly dictated: the

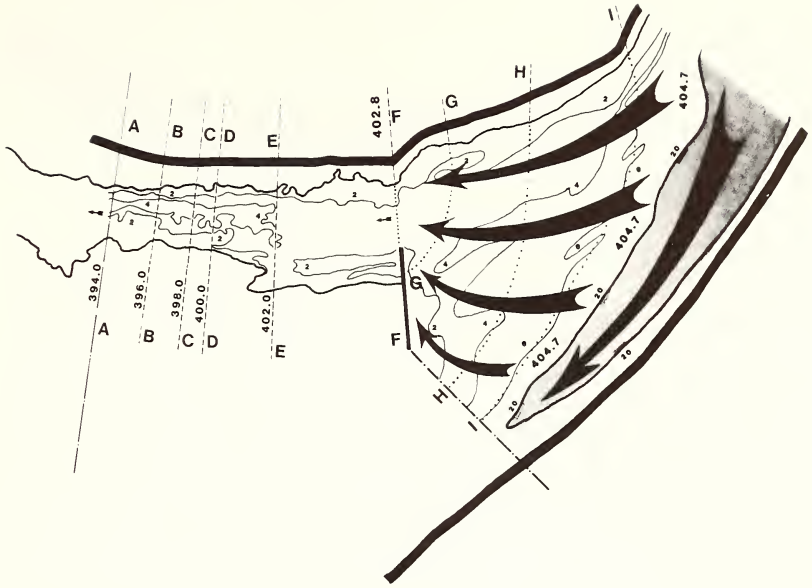

FIGURE 3. *Sketch of the 1903 map with wing dam.*

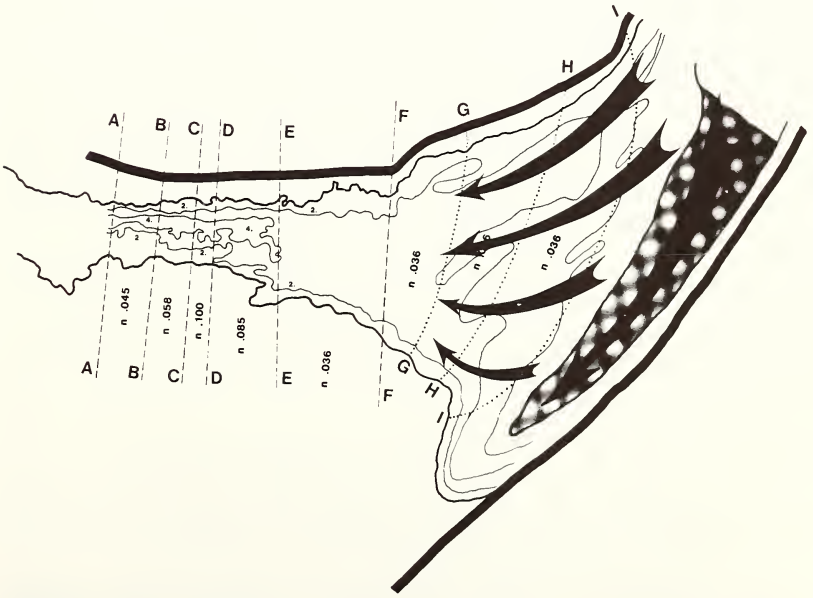

FIGURE 4. *Sketch of the 1903 map without wing dam.*

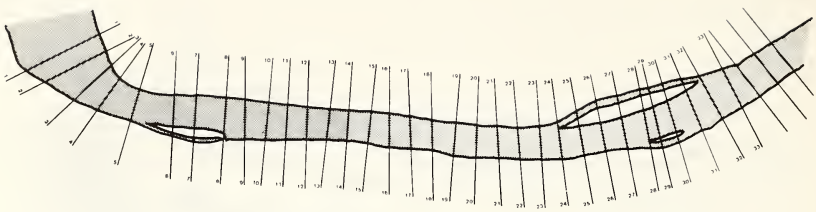

FIGURE 5. *Sketch of the Ohio River reach that ranges from the Ohio Chutes (roughly around cross section 1) and Sixmile Island (encompassing section 24 and section 32). The cross sections numbered in the sketch are those surveyed in 1911-14.*

numerical modeling of the Chutes. This phase could have been reduced to something slightly better than guesswork, were it not for the unexpected intervention of the 1903 map, which yielded contour lines of the whole Chutes region and surface water elevations at some cross sections. A schematic representation of this map, showing the wing-dam, is presented in Figure 3. This figure clearly shows that the Ohio River bed presents a diffuser-like behavior near the Chutes: the stream approaches the Chutes in a deep trench and overflows from it, almost orthogonally, to converge almost radially toward section FF. The computer simulation was therefore formulated by defining curved cross sections like II, HH, and GG, gradually closing onto section FF. After that section, the traditional rectilinear definition of cross section was kept intact. It was assumed that, at low discharges, the water velocity at the deep trench is negligible (since its depth exceeds 20 feet). The whole geometrical properties of the problem were therefore clearly defined. What was not known was the friction characteristic of each trunk from section to section, expressed in terms of the Manning's coefficient n.

It was therefore decided to infer the Manning's n of each trunk by using the measured elevations at each end. The process is a rather laborious one. It starts with the finding of all the flowrates Q_A, Q_B, ... Q_F that would make the sections AA, BB, ..., FF respectively critical. The lowest of these flowrates, if ever reached in the instance at hand, would be the controlling flowrate of the discharge. It was found that the first section to become critical is section FF, with a discharge of 7550 cfs. All other cross sections have tranquil regime for this flowrate.

For each trunk of the model, given a value of Manning's n, is always possible to find a flowrate Q that yields the given water elevations at the trunk ends. The locus Q vs. n, for each one of the trunks, has been plotted in Figure 6. In the figure we can see that, for the "critical" flowrate 7550 cfs, the Manning's n coefficients are at their lowest values, albeit the value of n for the trunk CD is more than three times the value of n for trunk FI.

Since we do not know with certainty the value of n for any one trunk of the reach under study, we should resort to educated guesses. These are:

a) Since the Army Corps of Engineers gives a global coefficient n = .03 for the region upstream of FF, we could assume that this is the value of n for the trunk FI. If that be the case, the discharge on the Chutes would be 6000 cfs;

b) Assuming that the trunk EF and FI have the same value of n, since they appear homogeneous in the map, we can obtain n = .035, with a flowrate of 5400 cfs;

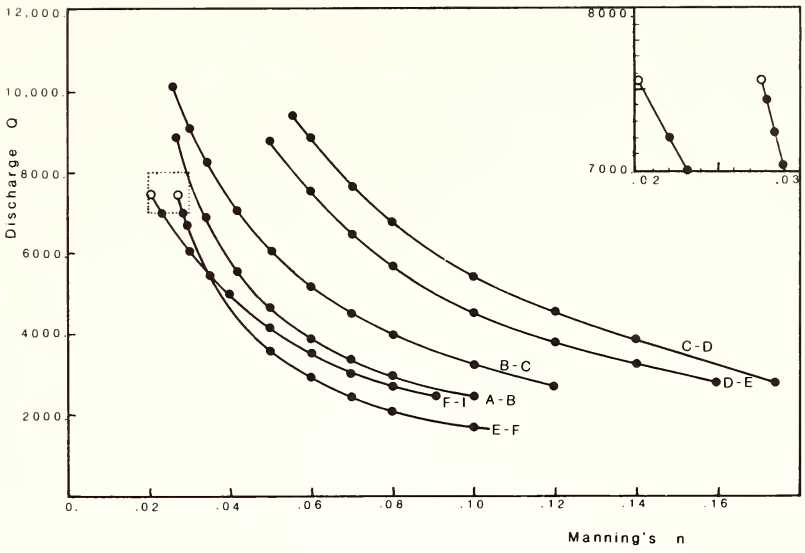

FIGURE 6. *The Ohio Chutes trunk's loci of the couples (Q,n) which yield the measured stages at both ends of each trunk.*

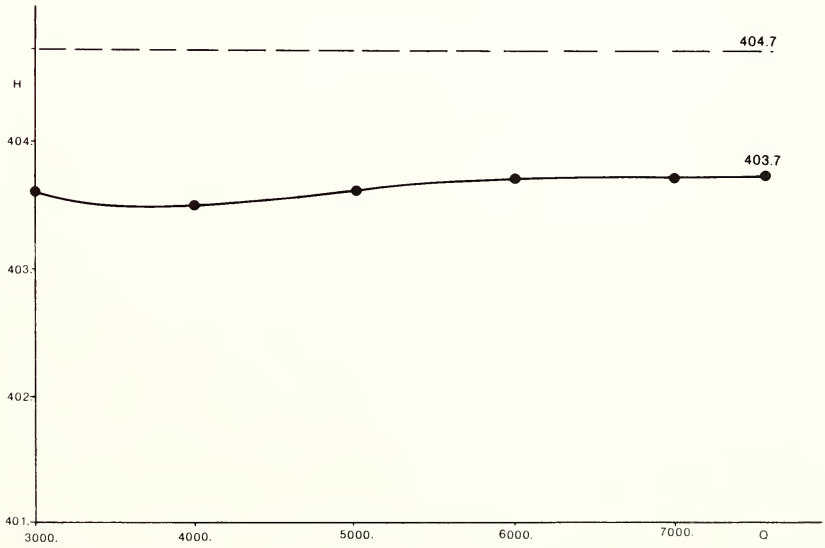

FIGURE 7. *Pool elevations corresponding to different discharges (and different roughnesses).*

c) We could argue that critical depth is actually reached in section FF, thereby concluding that the discharge is 7550 cfs.

We should recall that any one of the above alternatives yields exactly the whole free surface profile along the Chutes, as given by the 1895 measurements. The choice between any one of the above alternatives may depend on factors that depend on personal experience. It has been decided therefore to try all possible models, with different values of n, for flowrates corresponding to the range 3000 to 7550 cfs. The lower limit of 3000 cfs has been chosen because under that value the Manning's n for trunks CD and DE become unphysical.

For each set of n shown in the following table-like scheme

	AB	BC	CD	DE	EF	FI
Q = 3000	n = .078	n = .108	n = .170	n = .150	n = .046	n = .071
Q = 4000	n = .057	n = .079	n = .135	n = 115	n = .045	n = .055
Q = 5000	n = .046	n = .062	n = .106	n = .090	n = .037	n = .040
Q = 6000	n = .038	n = .050	n = .090	n = .075	n = .032	n = .030
Q = 7000	n = .033	n = .041	n = .076	n = .064	n = .029	n = .023
Q = 7550	n = .031	n = .039	n = .071	n = .059	n = .0278	n = .021

and for the corresponding flowrate a numerical simulation has been performed with the wall removed, as shown in Figure 4, and the elevation of the pool so obtained has been plotted in Figure 1.

The result shows clearly that the alternatives suggested at the beginning of this section, no matter how different they seem, yield almost the same result: the pool level after the wall has been removed is at least one foot below the 404.7 low water mark. The free surface profiles for the case Q = 7550 cfs with wing-dam and without it, are presented in Figure 8 and Figure 9 respectively.

Conclusion

Since the 1792 low water mark cannot be determined with certainty, the 1895 low water mark can be taken as a "conservative" substitute for it. It has been shown that the 404.7 ft 1895 low water mark was affected by a wing-dam whose removal, to restore the 1792 virgin conditions, lowers the water level to 403.7 (as shown in Figure 1-b for its effects on Six-mile Island). Since all the estimates are conservatives there is a definite probability that, at low waters, Six-mile Island was an Indiana peninsula. Comparison should be made between Figure 1-b, presenting the conservative estimate derived in this paper, and Figure 1-d, presenting the nowadays normal pool conditions with a stage of 420 ft. That comparison shows that, if the 403.7 stage is accepted as the boundary definition, Indiana's boundary with Kentucky is within the waters of the Ohio River. The argument is strong and, as it happened, persuasive. Whether the actual boundary, as sketched in the introduction, and the 403.7 stage boundary are coincident, is matter of no consequence, since the last has helped the formulation of the first.

Acknowledgments

The authors acknowledge the beneficial interaction with the researchers of the other phases of the project: Mr. Christopher Burke, Dr. Donald D. Gray, Dr. Wilton N. Melhorn, and Dr. Ramachandra A. Rao. Special thanks go to Attorney

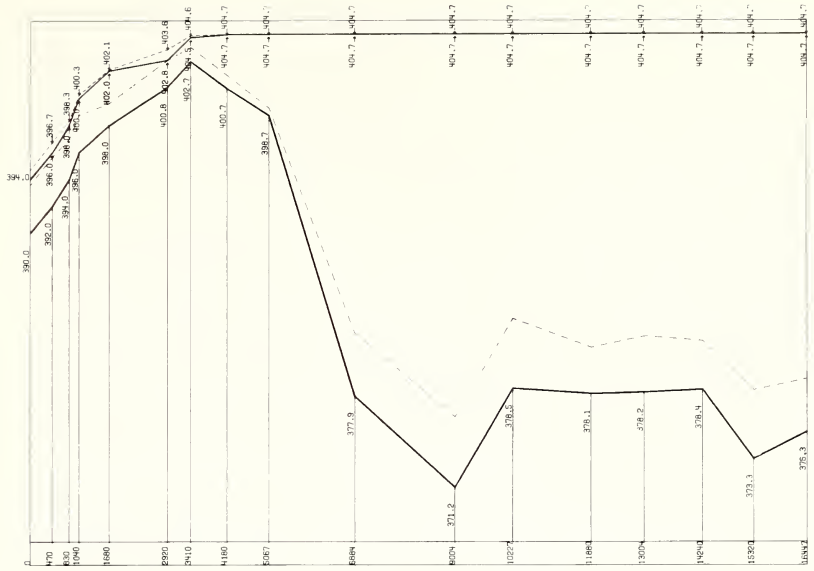

FIGURE 8. *Water profile along the Chutes for a discharge of 7550. cfs when the wing dam is present.*

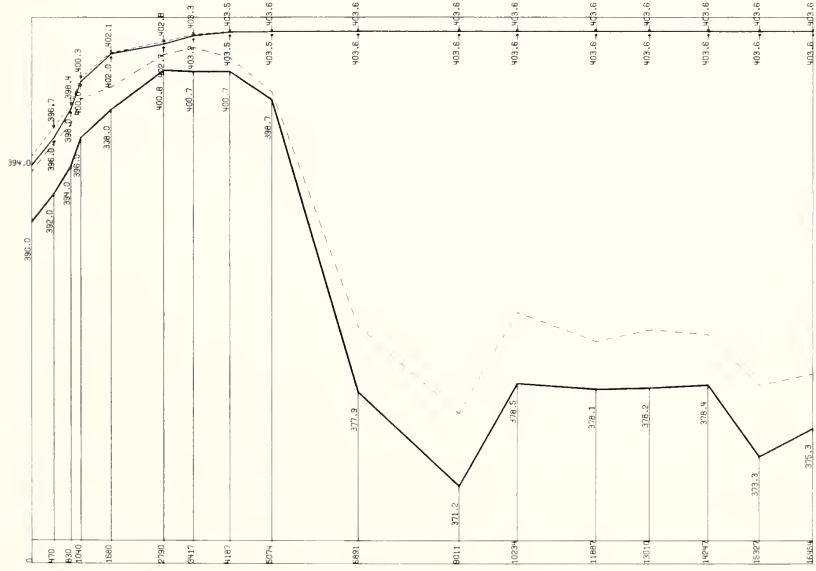

FIGURE 9. *Water profile along the Chutes for a discharge of 7550. cfs without the wing dam.*

General Linley E. Pearson, Special Counsel William E. Daily and Assistant Counsel Thad Perry for the opportunity to work on such an interesting project.

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The Barker Effect: The Case of the Circular Cylinder

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In the front stagnation region of a viscous fluid flow around a blunt body there occurs a kinetic energy conversion into pressure whose rate is affected by the viscosity of the fluid.

The earliest mention of viscosity influence on the pressure at the stagnation point of a sphere is made in a paper by Miss M. Barker (3). The author, having noticed in experiments undertaken upon suggestion of G.I. Taylor that velocity measurements with a Pitot-tube consistently gave, at low velocities, higher readings than expected from the Bernoulli theorem, that is

$$p_s - p_\infty = \frac{1}{2}\rho U_\infty^2, \qquad [1]$$

(where ρ is the liquid density, U_∞ is the free stream velocity, p_s is the stagnation pressure, and p_∞ is the pressure at infinity) tried to approach the problem by calculating the stagnation pressure by means of Stokes law.

For very small Reynolds numbers $Re = \rho U_\infty R/\mu$ the stagnation pressure on a sphere of radius R, given by Stokes law is

$$p_s - p_\infty = \frac{3}{2}\frac{\mu U_\infty}{R}, \qquad [2]$$

where μ is the viscosity of the liquid and R the radius of the sphere. For high Reynolds numbers the stagnation pressure is the same as for an ideal fluid, since viscosity effects, mostly in terms of boundary layer thickness, are negligible. Miss Barker argued that, since for low Reynolds numbers

$$\frac{1}{2}\rho U_\infty^2 << \frac{3}{2}\frac{\mu U_\infty}{R}$$

and for high Reynolds numbers, on the contrary,

$$\frac{1}{2}\rho U_\infty^2 >> \frac{3}{2}\frac{\mu U_\infty}{R}$$

both for low Re and for high Re an expression like

$$p_s - p_\infty = \frac{1}{2}\rho U_\infty^2 + \frac{3}{2}\frac{\mu U_\infty}{R} \qquad [3]$$

should approximate the data. While the mid Re are somewhat more difficult to explain by means of this intuitive law, which can be rewritten as

$$C_{ps} = \frac{p_s - p_\infty}{\rho U_\infty^2/2} = 1 + \frac{3}{Re}, \qquad [4]$$

the author presents some data, about which she admits: "The accuracy with which the points lie on this line is probably fortuitous, but a viscosity effect of a type suggested is clearly demonstrated". While Miss Barker's formulation of [4] was intuitive, the fact that the experimental points were falling on its graphical representation was not fortuitous. In fact, Homann (9) demonstrated that, for large Re, [4] is the relationship between C_{ps} and Re.

We point out that [4] was proposed for the stagnation pressure in front of a sphere, and not of a cylinder. Since there is no equivalent of Stokes law for the case of the cylinder, (10), the closest approach to an equation similar to [4] should be done with an Oseen type solution, or Lamb's solution (14), whose results are, however, valid only close to the cylinder's surface and for small Reynolds numbers.

The first author to conduct a comprehensive and systematic study of stagnation pressure on the front generator of a cylinder is Thom (17), followed by Thom (18). In the first paper the author, without mentioning the experimental finds of Miss Barker, proposes different ways for the calculation of the viscous overpressure at the stagnation point on a cylinder. By using a boundary layer type of reasoning he arrives at the expression

$$C_{ps} = 1 + \frac{2}{Re}\sqrt{-\frac{1}{2}\frac{d^2}{d\theta^2}\left(\frac{p - p_s}{\rho U_\infty^2/2}\right)}\Bigg|_s \quad , \qquad [5]$$

being θ the angular polar coordinate. He recognizes that the radicand equals 4 for ideal fluids, that it should be less than 4 for the most general case, and suggests a value 3.5 for high Reynolds numbers, but he fails to give a general expression for the radicand in terms of Reynolds numbers.

Nevertheless, the realization the $C_{ps} = 1 + 4/Re$ (Thom's law) is an upper limit for the actual value of C_{ps}, allows him to come up with experimental data that satisfy that inequality.

For smaller Reynolds numbers, Thom assumes that the stream function for the flow around the cylinder is of the form $\psi = \sin\theta\, S(r,\theta)$, where r is the radial polar coordinate, and, for small values of θ, he is able to integrate numerically the resulting equation by finite differences and, since of the conditions to be satisfied, two are on one end of the range and two are on the other, he adopts a trial and error technique, whereby, from an assumed tabulated relationship S(r), an improved function is obtained.

The derivation of Thom's law can be performed by following Homann (9) who suggests to calculate the pressure at the front stagnation generator by integrating the x component of the Navier-Stokes equations from $-\infty$ to -R, in the Cartesian plane, along the x direction of the uniform stream, that is

$$\frac{1}{\tilde{\rho}}\frac{\partial p}{\partial x} = \nu\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right] - u\frac{\partial u}{\partial x} \quad , \qquad [6]$$

where $\tilde{\rho}$ is the fluid density, y the conjugate Cartesian coordinate, and u the velocity of the flow along the x direction. The integration yields

$$\frac{1}{\bar{\rho}}(p_s - p_\infty) = \nu \frac{\partial u}{\partial x}\Bigg|_{-\infty}^{-R} + \nu \int_{-\infty}^{-R} \frac{\partial^2 u}{\partial y^2}\,dx - \frac{u^2}{2}\Bigg|_{-\infty}^{-R} \qquad [7]$$

Since $\partial u/\partial x$ is zero both at infinity and at the stagnation point, we can rewrite [7] as

$$\frac{p_s - p_\infty}{\bar{\rho}} = \frac{U_\infty^2}{2} + \upsilon \int_{-\infty}^{-R} \frac{\partial^2 \upsilon}{\partial y^2}\,dx$$

or

$$C_{ps} = 1 + \frac{2}{Re} \int_{-\infty}^{-1} \frac{\partial^2 \nu}{\partial \eta^2}\,d\xi\,, \qquad [8]$$

where $\eta = y/R$, $\xi = x/R$, $\upsilon = u/U_\infty$.

For the particular case of ideal fluid flow ($Re \to \infty$) the expression for υ can be shown to be

$$\upsilon = 1 + \frac{\eta^2 - \xi^2}{(\xi^2 + \eta^2)2}\,, \qquad [9]$$

which yields

$$\frac{\partial^2 \upsilon}{\partial \eta^2}\Bigg|_{\eta = 0} = \frac{6}{\xi^4}\,, \qquad [10]$$

If we substitute [10] into [8] we obtain, with Homann [9]

$$C_{ps} = 1 + \frac{4}{Re}\,, \qquad [11]$$

which is obviously valid only for $Re \to \infty$. For any finite value of Re it is always $\frac{\partial^2 \upsilon}{\partial \eta^2} \leq \frac{6}{\xi^4}$ because the velocity reduction, caused by viscosity effects, tends to seperate the streamlines further away than in the ideal case along the approach x axis. We can in fact assume that the streamfunction around the approach x axis can be written as $\psi_i\left(\xi, \frac{\eta}{\eta_o(\xi)}\right)$ if $\psi_i(\xi, \eta)$ is the ideal fluid steamfunction and $\eta_o(\xi)$ is a "spread" function, always larger than 1 for any ξ. Then,

$$\frac{\partial^2 \upsilon}{\partial \xi^2}\Bigg|_{\eta = 0} = \frac{\partial^3 \psi}{\partial \eta^3}\Bigg|_{\eta = 0} = \frac{\partial^3 \psi_i}{\partial \eta^3}\Bigg|_{\eta = 0} \frac{1}{\eta_o^3(\xi)} \leq \frac{\partial^3 \psi_i}{\partial \eta^3}\Bigg|_{\eta = 0}$$

Therefore [11] is a limit law for C_{ps}: for no value of Re one can find a value of C_{ps} larger than one given by [9].

As a concluding remark, referring to Figure 1, where the viscous overpressure coefficient C_{ps} -1 is plotted against Re we can observe that most reliable

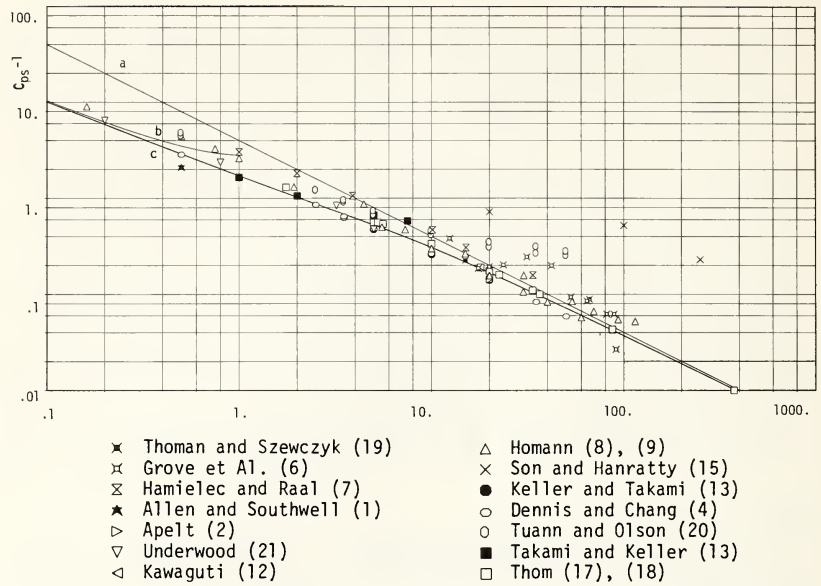

FIGURE 1. *The coefficient (C_{ps}-1) as a function of Re. Curve a, Thom's law (C_{ps}-1 = 4/Re); curve b, after Lamb solution's pressure coefficient; curve c, proposed fittings(5).*

data follow Lamb's solution for low Re and Thom's law for high Re, while Thom's law is an upper limit for any Re. The curve c fitting the data has been derived by applying the result of an analytic model, which is the subject of another paper just submitted for publication (5).

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ENTOMOLOGY

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ABSTRACTS

A Comparison of the Pathological Effects on the Midgut of the European Corn Borer Treated with Bacillus thuringiensis and Bacillus subtilis: A Preliminary Report. PHILLIP L. EICHMAN and HAROLD L. ZIMMACK, Department of Biology, Ball State University, Muncie, Indiana 47306.——Research is currently being conducted to compare the pathological effects of *Bacillus thuringiensis* and *Bacillus subtilis* on the midgut of the European corn borer (*Ostrinia numilalis*). *Bacillus thuringiensis* is known to be a virulent pathogen of many insects and to cause pathological damage to the midgut of the corn borer. Some degree of pathology has been observed in corn borers treated with *B. subtilis*, however, no quantitative data have been gathered. This study will attempt to compare quantitatively and qualitatively the pathology caused by these two bacterial species.

The research will include mortality studies and histological examination of midgut tissues utilizing both the light and transmission electron microscopes. It is hypothesized that there will be observable differences in the pathology caused by these two organisms, and that such a comparison may be employed to evaluate future biological control organisms.

Status of Gypsy Moth, Lymantria dispar (Linnaeus), (Lepidoptera, Lymantria) in Indiana. JOHN J. FAVINGER, Indiana Department of Natural Resources, Indianapolis, Indiana 46204.——Gypsy moth has become an increasingly serious defoliator of shade and forest trees in the eastern U.S. since its escape from a Medford, Massachusetts laboratory in 1869. Gypsy moth was confined to the New England states until the early 1950s when it broke through to the Hudson River. The use of DDT slowed its natural spread for a number of years, but after DDT sprays were discontinued, the pest spread quickly to other eastern states and Michigan.

In 1980 gypsy moth larvae defoliated 5.1 million acres of forest land and this area was more than doubled in the spring of 1981. Three years of successive defoliation usually results in a high mortality of oak and other susceptible deciduous hosts while one defoliation will often kill coniferous trees.

Extensive trapping for many years using a sex-pheromone (disparlure) sticky trap, disclosed only an occasional lone male gypsy moth in Indiana. Last year (1980) there was a multiple find in Vigo County. Intensive trapping this year disclosed a total of 32 moths at 11 locations in close proximity to the 4 moths captured in 1980. Fifteen moths were captured at one location.

Another significant area is in Elkhart County where a total of 16 moths were found in 8 trap locations.

Another multiple find was 3 moths at one Wayne location. Single finds were

recorded from 2 places in Allen and Tippecanoe, and 1 each in Bartholomew, Boone, Lake, LaPorte, and at a separate Wayne County location for a total of 60 moths.

Indiana is probably several years away from defoliating populations of gypsy moth but it would appear that there are incipient infestations in Elkhart and Vigo counties although, to date, no life stages other than adult males have been noted.

Aside from timber depredation the recreational use of parks, woodlands and camp grounds is greatly diminished by the presence of gypsy moth caterpillars in great numbers.

New Indiana Records of Hemiptera and Homoptera. ROBERT R. HEATON and VIRGIL R. KNAPP, Indiana Department of Natural Resources, Indianapolis, Indiana 46204——Thirty three new records of Tingidae, Cicadellidae, Fulgoridae, and Aphididae from the state are listed with annotations and hosts. Many of these species, it is believed, have been established in the state but have not previously been reported by scientific name. A couple are new inhabitants of the state as well as of the United States.

New Indiana Records

The different species are not listed in any of the varied systematic arrangements but alphabetically by genera and species within genus and family.

The initials of the collectors of all specimens are placed in parentheses after each record. The collectors and their initials are: H. R. Bollinger (HRB); J. A. Clark (JAC); R. Bruce Cummings (RBC); Robert R. Heaton (RRH); G. Earl Huff (GEH); and Virgil R. Knapp (VRK).

New Indiana Records of Tingidae

Stephanitis rhododendri (Horvath 1905) Rhododendron lace bug
Rhododendron sp. Marion Co., In. June 26, 1974 (RRH).
Stephanitis takeyai (Drake & Maa 1905) Andromeda lace bug
Pieries japonica Marion Co., In. June 20, 1974 (RRH).

New Indiana Records of Cicadellidae

Balclutha punctata (Fabricius, 1775)
Grasses Morgan Co., In. October 20, 1975 (RRH).
Erythroneura aclys McAtee, 1920
Ceris canadensis Hendricks Co.,. In. May 11, 1977 (RBC).
Erythroneura bistrata McAtee, 1920
Ceris canadensis Hendricks Co., In. May 11, 1977 (RBC).
Erythroneura tricincta Fitch, 1851 Threebanded leafhopper
Nyssa sylvatica Marion Co., In., June 25, 1974 (RRH).
Eutettix luridus (Van Duzee, 1890).
Lespedeza Morgan Co., In. October 1, 1974 (RRH).
Fieberiella florii (Stal, 1864).
Red raspberry Marion Co., In., July 22, 1976 (JAC).
Macropsis sordida (Van Duzee, 1894).
Birch Wabash Co., In., July 1, 1974 (HRB).
Orientus ishidae (Matsamura, 1902).
Crataegus sp. Vigo Co., In., July 3, 1974 (GEH).
Scaphoideus opalinus Osborn, 1905
Rhus sp. Marion Co., In., August 2, 1976 (JAC).
Sorhoanus debilis (Uhler) 1876
Sweeping weeds, Marion Co., In., June 22, 1979 (RRH).

New Indiana Records of Fulgoridae

Achilinae (*Achilidae*)

Catonia bicinctura Van Duzee, 1915
Sweeping Morgan Co., In., September 22, 1976 (RRH).
Catonia impunctata (Fitch, 1830)
Weeds Morgan Co., In., July 25, 1977 (RRH).
Catonia lunata Metcalf, 1923
Peony. Morgan Co., In., September 22, 1976 (RRH).

Delphacinae (*Delphacidae*)

Copicerus irroratus Schwarz, 1802, on house
Morgan Co., In., October 2, 1975 (RRH).
Delphacodes detecta (Van Duzee, 1897)
Grass Spencer Co., In., October 3, 1974 (RRH).
Pissonotus brunneus Van Duzee, 1894
Meadow Morgan Co., In., July 25, 1977 (RRH).
Pissonotus delicatus Van Duzee 1897
Weeds Morgan Co., In., October 9, 1980 (RRH).

Derbinae (*Derbidae*)

Cedusa edentula (Van Duzee, 1912)
Meadow Morgan Co., In., July 28, 1977 (RRH).
Cedusa vulgaris (Fitch, 1851)
Weeds in Woods, Morgan Co., In., June 22, 1979 (RRH).

New Indiana Records of Aphids

Amphorophora rubi (Kalt., 1843)
Black Raspberry, LaPorte Co., In., July 24, 1974 (RBC).
Aphis carduella Walsh 1963
Cirsium vulgare (Thistle) White Co., In., August 22, 1978 (VRK).
Aphis citricola Vander Goot 1912
Amelancher sp. LaPorte Co., In., June 11, 1976 (RBC).
Brachycolus asparagi Mordvilko, 1929 Eastern Asparagus Aphid
Asparagus offinalis Marion Co., In., August 27, 1980 (VRK).
Det. Mrs. M. B. Stoetzel
Chaitophorus populifolii Gill & Pal. 1928
Populus deltoides Marshall, White Co., In., August 8, 1973 (VRK).
Eomacrosiphon nigromaculosus (Mac Dougall, 1926).
Rose, Marion Co., In., November 2, 1976 (VRK).
Hyadaphis tataricae (Azienberg, 1935).
Honeysuckle, tartarican, Jasper Co., In., September 22, 1980 (RBC).
Det. Mrs. M. B. Stoetzel
Macrosiphum geranii (Oestlund, 1887).
Ostrya virginiana Hophornbeam Marion Co., In., May 19, 1977 (VRK).
Melanocallis fumipennellus (Fitch, 1855).
Black Raspberry LaPorte, Co., In., May 31, 1977 (RBC).
Neophyllaphis araucariae Takahashi, 1937.
Araucariae excelsa, Marion Co., In., January 1967 (in greenhouses) (VRK).
Det. Miss. L. Russell
Pemphigus bursarius (Linn. 1758).
Lombardy poplar, Daviess Co., In., June 9, 1977 (VRK).

Sanbornia juniperi Pergande, 1920
Canartii juniper, Elkhart, Co., In., July 18, 1972 (RBC).
Sitobion ptericolens (Patch, 1919).
Bracken Fern, Pulaski Co., In., September 25, 1976 (VRK).

Recent Records of the Milkweed Beetle *Tetraopes melanurus* Schönher (*Cerambycidae*) from Indiana. MICHAEL P. KOWALSKI, Bloomington, Indiana 47401.——In July 1980 two male *Tetraopes melanurus* were collected 1.5 km south of Griffey Reservoir, Bloomington, Monroe County. These specimens represent the first reported occurence of this species in Indiana since Blatchley's (1910) listing of it from Posey County. In July 1981 another male was collected from a field 0.5 km southeast of Griffey Reservoir, and subsequent field work east of Bloomington has uncovered a small breeding population. One of the 1980 specimens is presently in the collection of the University of California-Berkley, and the other is in the collection of Indiana University-Bloomington.

The Distribution of the Walking Stick *Anisomorpha ferruginea* (Beauv.) in Indiana. MICHAEL P. KOWALSKI, Bloomington, Indiana 47401.——On October 18, 1979 a female *Anisomorpha ferruginea* was collected in a wood edge located 10 km east of Bloomington, Monroe County. The fact that the only reference to this species in Indiana in the literature is in Blatchley's *Orthoptera of Northeastern America* prompted me to update the status of this walking stick in the state. The counties in which *A. ferruginea* has been collected are Crawford, Jackson, Monroe, and Posey. Specimens are in the collections of the National Museum of Natural History, Purdue University, St. Francis College, and Indiana University-Bloomington.

Species Composition and Feeding Success of Mosquitoes Attracted to Dogs. ROBERT R. PINGER, Public Health Entomology Laboratory, Ball State University, Muncie, Indiana 47306.——During the summers of 1980 and 1981, field studies were conducted in Muncie, Indiana to determine the species composition of mosquitoes attracted to dogs. Dogs were placed in the field in modified kennel traps which allowed mosquitoes to approach and feed on the dogs but not escape. Trapped mosquitoes were collected at the end of each 3 hour testing period and identified to species. *Aedes trivittatus* constituted the greatest percentage of the catch each year with 73.6% in 1980 and 80.5% in 1981. *Aedes vexans* made up only 6.3% and 6.2% of the collections in 1980 and 1981 respectively. In contrast, *Ae. vexans* made up 22.5% and 49.5% of New Jersey light trap collections from the same site each year. Other mosquito species collected in the kennel traps were *Ae. canadensis, Ae. sticticus, Ae. stimulans, Ae. triseriatus, Anopheles punctipennis, Coquillettidia perturbans, Culex erraticus, Cx. pipiens-restunans, Psorophora columbiae, Ps. ferox* and *Ps. horrida.* In summary, a strong mosquito-host association was found between *Ae. trivittatus* and dogs.

Confirmation of a LaCrosse virus (California Encephalitis group) focus in Delaware County. ALICE K. THOMAS and ROBERT R. PINGER, Ball State University, Muncie, Indiana 47306 and PAUL R. GRIMSTAD, University of Notre Dame, Notre Dame, Indiana 46556.——In 1978, the first isolation of LaCrosse virus from Indiana mosquitoes was reported from Delaware County. The isolation was from a pool of four *Aedes triseriatus* collected from a large wood lot ten miles north of Muncie. In 1980, a study was conducted using oviposition traps to determine whether infected larvae or pupae could be recovered from the area. One isolation of LaCrosse virus was made from fifteen pupae reared from eggs collected on July 28, 1980. This indicates that a focus of LaCrosse virus activity exists in this area.

Notorious Rattus norvegicus the Zoonotic Disseminator. WALTER WEBER, Indianapolis, Indiana 46217.——Norway rats have a bad reputation. That image is not improved by a review of medical literature (human or veterinary). Rats are involved in germ warfare playing an important part in perpetuation of over seventy pathogenic organisms. While many people voice concern about man-made environmental contamination, relatively few recognize the potential hazards of naturally occurring zoonotic organisms silently lurking in Norway rats, making them enemy number one ecologically and epidemiologically. A partial list of public health importance follows. Bacterial: Brucella abortus, Borellia spp., Campylbacter fetus fetus, Erysipelothrix rhusipathae, Leptospira 17 serovars, Listeria monocytogenes, Mycobacterium avium, M. bovis, Pasteurella haemolytica, P. multocida, P. pneumotropica, P. pseudotuberculosis, P. tularensis, Pseudomonas pseudomallei, Salmonella 18 serotypes, Spirillium minus, Staphylococcus aureus, Streptobacillus moniliformis, Yersinia pestis. Mycotic: Histoplasma capsulatum, Microsporum gypseum, Trichophyton mentagrophytes. Rickettsial: Coxiella burneti, Rickettsia akari, R. rickettsii, R. siberica, R. typhi. Viral: Lymphocytic choriomeningitis, Pseudorabies. Protozoan: Balantidium coli, Entamoeba histolytica, Giardia lamblia, Leishmania donovani, Nosema cuniculi, Pneumocystis carinii, Sarcocystis lindermanni, Toxoplasma gondii, Trypansoma cruzi. Cestodes: Hymenolepis diminuta, H. nana, Raillientiniasus garrison, Sparganosis spirometra. Nematodes: Ancylostoma braziliense, A. caninium, Angiostrongylus cantonensis, Capillaria hepatica, Gnathostoma spinigererum, Nippostrongylus brassiliensis, Strongyloides stercoralis, Toxocara canis, Trichinella spiralis, Trichostrongylus colubriformis. Trematodes: Echinostoma ilocanum, Heterophyes heterophyes, Paragonimus westermani, Schistoma incognitum, S. japonicum, S. mansoni.

Transmission of Corn Genotype Attractiveness to Ovipositing European Corn Borer[1] Moths to Hybrid Combinations

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Introduction

Corn genotypes differ in their attractiveness to European corn borer moths, *Ostrinia nubilalis* (Hbn.), as measured by the number of eggs laid on them (1, 4). The ratio of this attractiveness may be as great as 1 to 25. These relative differences hold throughout the attractive period in the life of the corn plants. The factors responsible for differences in attractiveness are independent of those for survival resistance and for tolerance and if transmissible into single-cross combinations, they offer another facet in the biological control of the corn borer through plant resistance.

Data obtained by other observers (5,6,7,8,9) indicated that differences in attractiveness existed in early corn hybrids. However, since little was known of the attractiveness of inbred lines comprising them, it could not be determined to what extent this attractiveness was due to the inbred lines in their pedigrees.

In 1944-1946 studies were conducted at Lafayette, Indiana, to determine the relationship of the attractiveness of single-crosses and the inbred lines comprising them. All single-crosses involving 3 low and 3 high attractive inbred lines were tested.[2]

Methods and Procedures

All-possible single-cross combinations of 3 low and 3 high attractive inbred lines were tested in 15 x 15 Latin squares with 3 single plant hills per plot. Other single-cross tests were five single plant hill plots, planted in completely randomized blocks with 6 replications.

Generally, corn was planted in late April and each hill was immediately covered with commercial wax paper domes to accelerate germination and protect the young plants from early adverse environmental conditions. At the start of oviposition plants were examined every third day and egg masses were marked, counted and number of eggs recorded by plant. At a date near the middle of the egg-laying period, each plant height was measured to the tip of the longest leaf held upright.

Everly *et al* (4) demonstrated that the differences between low and high attractive inbred lines increased in direct proportion with an increase in level of oviposition. To compare these single-crosses from season to season and from experiment to experiment, the number of observed eggs per plant was adjusted for differences in plant height at mid-oviposition by statistical regression methods (3). The adjusted number of eggs per plant was standardized to a mean of 40 eggs per plant, by proportional methods based on the level of oviposition for each year.

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[1]Lepidoptera: Pyralidae

[2]Although information was gathered between 1944 and 1946, it is applicable to European corn borer research today.

1944 Single-Cross Tests

In 1944, 15 single-crosses comprising combinations of 3 low attractive inbred lines, Illinois A, Illinois R4 and Wisconsin W23, and 3 high attractive inbred lines, USDA CI.540, Iowa L317 and Indiana WF9 were tested. The data on the amount of oviposition and the height of the corn are given in Table 1.

Statistical analysis indicated highly significant differences among the single-crosses, both in respect to height at mid-oviposition and in the number of eggs laid. After adjusting the number of eggs laid per plant for differences in height, highly significant differences still existed among the entries.

The single-cross Ill. A x Wis. W23, which as inbred lines were among the least attractive, received the fewest eggs. It was significantly less attractive than all the others except Wis. W23 x Ind. WF9 and Ill. A x Ind. WF9. The single-cross comprising the 2 high attractive inbred lines Ind. WF9 and Ia. L317 was in the high attractive group receiving the most eggs but did not differ significantly from others in this group.

TABLE 1. *Plant height and eggs laid by European corn borer moths during early summer on single-cross combinations of three low and three high attractive corn inbred lines. 1944. Lafayette, Indiana.*

Single Cross	Ave. Height in inches at 50% Oviposition	Number of eggs laid per plant		
		Observed	Adjusted for Height Differences	Standardized to Mean of 40.0
Low attractive x *Low attractive*				
Ill. A x Wis. W23	38.8	43.5	27.7	16.0
Ill. A x Ill. R4	35.0	54.7	58.7	34.0
Wis. W23 x Ill. R4	38.6	69.4	61.3	35.5
Av.	37.5	53.2	49.2	28.5
Low attractive x *High attractive*				
Wis. W23 x Ind. WF9	39.4	54.3	43.5	25.2
Ill. A x Ind. WF9	38.3	56.1	49.0	28.4
Ill. R4 x CI.540	31.0	37.0	54.5	31.6
Ill. A x CI.540	34.6	51.0	56.4	32.7
Wis. W23 x CI.540	37.2	72.6	66.2	38.4
Ill. R4 x Ia. L317	36.2	72.6	69.2	40.1
Ill. R4 x Ind. WF9	37.5	98.8	94.4	54.7
Ill. A x Ia. L317	37.9	105.1	99.4	57.6
Wis. W23 x Ia. L317	36.9	107.4	105.1	60.9
Av.	36.6	72.8	70.8	41.1
High attractive x *High attractive*				
CI.540 x Ind. WF9	35.8	55.6	56.9	33.0
CI.540 x Ia. L317	31.4	70.4	94.6	54.7
Ind. WF9 x Ia. L317	37.9	98.6	98.9	57.3
Av.	35.0	74.8	83.5	48.2
L.S.D. 19:1	1.5	21.9	21.4	12.6

1945 Single-Cross Tests

The 1944 experiment was repeated in 1945, except inbred line Indiana Tr was substituted for USDA CI.540, since single-crosses with this line averaged 4 inches shorter in growth than the other combinations tested in 1944.

Experiments were planted on 2 dates to compare the attractiveness of these single-crosses under both first and second generation oviposition. However, the earlier planting was destroyed by livestock before any data were obtained, and only the planting made June 22 was available for study.

Statistical analysis showed highly significant differences among the entries in respect to all the variables measured. However, the number of eggs laid per plant on the different single-crosses was not significantly correlated with height at 50% oviposition or stage of development as measured in days from July 1 to mid-silking. Therefore, no adjustments were warranted in the number of eggs laid per plant (Table 2).

Although these single-crosses were tested under greatly differing environmental conditions and at a much later stage of plant development, the number of eggs laid per plant agreed consistently with those recorded in 1944. Ill. A x Wis.

TABLE 2. *Plant height and eggs laid by European corn borer moths during late summer on single-cross combinations of three low and three high attractive corn inbred lines. 1945. Lafayette, Indiana.*

Single Cross	Ave. Height in inches at 50% Oviposition	Mean Silk date days after July 1	No. of Eggs Laid Per Plant	
			Observed	Standardized to Mean of 40.0
Low attractive x *Low attractive*				
Ill. A x Wis. W23	73.3	58.8	8.9	9.9
Ill. A x Ill. R4	71.6	61.5	23.5	26.2
Wis. W23 x Ill. R4	78.3	60.3	24.3	27.1
Av.	74.4	60.2	18.9	21.1
Low attractive x *High attractive*				
Ill. A x Ind. WF9	71.5	58.4	12.5	13.9
Wis. W23 x Ind. WF9	76.2	59.2	14.5	15.9
Wis. W23 x Ia. L317	79.7	63.1	30.5	34.0
Ill. A x Ind. Tr	68.1	57.8	31.7	35.3
Ill. A x Ia. L317	77.4	61.5	35.4	39.4
Wis. W23 x Ind. Tr	76.9	59.1	37.2	41.4
Ill. R4 x Ind. WF9	76.4	61.6	40.3	44.9
Ill. R4 x Ia. L317	82.8	62.3	56.7	63.2
Ill. R4 x Ind. Tr	73.2	61.1	57.2	63.7
Av.	75.8	60.4	35.1	39.1
High attractive x *High attractive*				
Ind. Tr x Ind. WF9	75.2	58.9	41.8	46.6
Ind. WF9 x Ia. L317	82.5	63.0	48.3	53.8
Ind. Tr x Ia. L317	77.8	61.3	76.4	85.1
Av.	78.5	61.1	55.5	61.8
L.S.D. 19:1	2.0	1.1	16.1	17.9

W23 was again outstandingly unattractive. The most attractive single-cross was Ind. Tr x Ia. L317. The single-crosses involving Ill. A were among the 8 receiving the fewest eggs.

1946 Single-Cross Tests

The same combinations of single-crosses tested in 1945 were planted May 8 and retested under early summer oviposition in 1946.

Statistical analysis indicated highly significant differences among the single-crosses, both in respect to height and in the number of eggs laid (Table 3). After adjusting the number of eggs laid per plant for differences in height, highly significant differences still existed among the entries.

In the 1946 tests the single-cross Ill. A x Wis. W23 was not quite as unattractive as in the previous 2 seasons although it did not differ significantly from those single-crosses receiving fewer eggs. The single-cross Ind. Tr x Ia. L317 was again the most attractive one.

A comparison of the number of eggs laid on the single-crosses tested in 2 or more of the 3 seasons shows a very close agreement in the number of eggs received.

TABLE 3. *Plant height and eggs laid by European corn borer moths during early summer on single-cross combinations of three low and three high attractive corn inbred lines. 1946. Lafayette, Indiana.*

Single Cross	Ave. Height in inches at 50% Oviposition	Number of eggs laid per plant		
		Observed	Adjusted for Height Differences	Standardized to Mean of 40.0
Low attractive x *Low attractive*				
Ill. R4 x Wis. W23	27.4	25.9	17.8	20.5
Ill. A x Wis. W23	26.6	24.0	21.2	24.4
Ill. A x Ill. R4	23.6	17.3	31.2	36.0
Av.	25.9	22.4	23.4	27.0
Low attractive x *High attractive*				
Wis. W23 x Ind. WF9	28.1	23.7	12.6	14.5
Ill. A x Ind. WF9	27.7	29.8	20.9	24.1
Ill. R4 x Ind. WF9	27.0	36.3	31.3	36.1
Wis. W23 x Ind. Tr	27.4	40.1	32.9	37.9
Ill. A x Ind. Tr	24.0	23.0	34.7	40.0
Ill. R4 x Ind. Tr	24.8	30.2	37.4	43.1
Ill. R4 x Ia. L317	24.4	29.6	39.0	45.0
Wis. W23 x Ia. L317	26.2	43.9	43.4	50.0
Ill. A x Ia. L317	24.5	37.9	46.8	53.9
Av.	26.0	32.7	33.2	38.3
High attractive x *High attractive*				
Ind. WF9 x Ind. Tr	28.8	54.2	39.2	45.2
Ind. WF9 x Ia. L317	26.4	54.4	52.7	60.7
Ind. Tr x Ia. L317	25.0	48.9	55.0	63.4
Av.	26.7	52.5	49.0	56.4
L.S.D. 19:1	1.4	15.9	13.9	16.0

This is especially significant when we consider that each test was grown under different environmental conditions and stage of corn development.

Comparison of the 1944, 1945 and 1946 Tests

The single-cross Ill. A x Wis. W23 was outstanding in its unattractiveness in 1944 and 1945. In 1946 it was still among the least attractive single-crosses. All combinations involving Ill. A as one parent, with the exception of the single-cross Ill. A x Ia. L317 in 1944 and 1946, were among the least attractive combinations.

The single-cross Ind. Tr x Ia. L317 was the most attractive in 1945 and 1946, the 2 years it was tested. This high attractiveness is further substantiated by data from other tests in 1946. The high degree of attractiveness of Ia. L317 is indicated by the fact that in all years the single-crosses containing this line as one parent were among the 8 most attractive. In 1945 some reversals occurred, particularly those crosses involving Ia. L317 with Ill. A and Wis. W23.

TABLE 4. *Comparison of eggs laid by corn borer moths on single-crosses of three low and three high attractive corn inbred lines. 1944, 1945, 1946. Lafayette, Indiana.*

Single Cross	Number of eggs adjusted for height differences and standardized to a mean of 40.0 eggs per plant.			
	1944	1945	1946	Average
Low attractive x *Low attractive*				
Ill. A x Wis. W23	16.0	9.9	24.4	16.8
Ill. A x Ill. R4	34.0	26.2	36.0	32.1
Ill. R4 x Wis. W23	35.5	27.1	20.5	27.1
Av.	28.5	21.1	27.0	25.3
Low attractive x *High attractive*				
Wis. W23 x Ind. WF9	25.2	15.9	14.5	18.5
Ill. A x Ind. WF9	28.4	13.9	24.1	22.1
Ill. A x Ind. Tr	—	35.3	40.0	37.6
Wis. W23 x Ind. Tr	—	41.4	37.9	39.6
Ill. R4 x Ind. WF9	54.7	44.9	36.1	45.2
Wis. W23 x Ia. L317	60.9	34.0	50.0	48.3
Ill. R4 x Ia. L317	40.1	63.2	45.0	49.4
Ill. A x Ia. L317	57.6	39.4	53.9	50.3
Ill. R4 x Ind. Tr	—	63.7	43.1	53.4
Av.	44.4	39.1	38.3	40.5
High attractive x *High attractive*				
Ind. WF9 x Ind. Tr	—	46.6	45.2	45.9
Ind. WF9 x Ia. L317	57.3	53.8	60.7	57.3
Ind. Tr x Ia. L317	—	85.1	63.4	74.2
Av.	57.3	61.8	56.4	59.1
L.S.D. 19:1	12.6	17.9	16.0	13.2

L.S.D. 19:1 for Comparing Single-Crosses from Year to Year

1944 and 1945	1944 and 1946	1945 and 1946
21.8	17.3	20.7

In comparing the years 1945 and 1946, only the single-cross, Ind. Tr x Ia. L317 differed significantly in the number of eggs received. Between the years 1944 and 1946, only Ill. R4 x Ind. WF9 differed significantly in the 2 years. Between 1944 and 1945, 2 single-crosses, Wis. W23 x Ia. L317 and Ill. R4 x Ia. L317, received a significantly different number of eggs. Of a total of 45 single-crosses tested during the 3 years, only 4 differed significantly in 2 of the 3 years and none differed in all 3 years (Table 4). Such constancy in performance indicates strongly that the factors responsible for differences in attractiveness are genetic in nature and transmitted from inbred lines into single-cross combinations.

1947 Single-Cross Tests

Schlosberg (10) who continued studies in 1947, tested a group of high and low attractive inbred lines in single-cross combinations. Of the 12 studied, 3 represented crosses of low attractive lines, 3 crosses of high attractive lines and 6 were crosses of low x high attractive inbred lines.

The level of oviposition was very high, averaging approximately 100 eggs per plant. The group of single-crosses comprising low attractive inbred lines averaged 47.5 eggs per plant when height differences were taken into account, and 18.5 eggs when standardized to a mean of 40 eggs per plant. The intermediate group, comprising crosses of a low x high attractive inbred lines averaged 97.0 eggs per plant,

TABLE 5. *Plant height and eggs laid by European corn borer moths during early summer on single-cross combinations of three low and three high attractive corn inbred lines. 1947. Lafayette, Indiana. (Schlosberg—Annual Report 1947)**

Single Cross	Ave. Height in inches at 50% Oviposition	Number of eggs laid per plant		
		Observed	Adjusted for Height Differences	Standardized to Mean of 40.0
Low attractive x *Low attractive*				
Ill. A x Ill. R4	33	20.8	33.7	13.1
Ill. A x Wis. W23	33	33.6	46.5	18.1
Wis. W23 x Ill. R4	38	73.6	62.6	24.4
Av.	35	42.7	47.6	18.5
Low attractive x *High attractive*				
Ill. A x Ind. Tr	36	88.0	86.6	33.7
Ill. A x Ia. L317	34	80.0	88.1	34.3
Wis. W23 x Ind. Tr	40	110.4	89.8	35.0
Ill. R4 x Ind. Tr	37	97.6	91.4	35.6
Ill. R4 x Ia. L317	35	91.2	94.6	36.8
Wis. W23 x Ia. L317	37	137.6	131.4	51.2
Av.	36	100.8	97.0	37.8
High attractive x *High attractive*				
Ind. P8 x Ia. L317	34	147.2	155.3	60.5
N.J. A64 x Ia. L317	35	163.2	166.6	64.9
Ind. Tr x Ia. L317	36	185.6	184.2	71.7
Av.	35	165.3	168.7	65.7
L.S.D. 19:1		51.2	46.4	18.1

*Used with permission of the USDA Bureau of Entomology.

37.8 when standardized to a mean of 40 eggs. The group of single-crosses composed of 2 attractive inbred lines averaged 168.7 eggs per plant or 65.7 when standardized to 40 eggs per plant, these single-crosses averaged about the same number of eggs per plant as they received in 1944, 1945 and 1946. Exceptions were single-crosses Ill. A x Ill. R4 which had fewer, and Ill. R4 x Ia. L317, Ill. A x Ia. L317 and Ill. R4 x Ind. Tr which received more eggs (Table 5).

TABLE 6. *Plant height and eggs laid by European corn borer moths on 41 corn genotypes top-crossed on Illinois A and Iowa L317, adjusted for height and standardized to 40 eggs per-plant, with standardized number of eggs laid on them as inbreds in 1945. Lafayette, Indiana, 1946.*

Genotype	Height Inches		Number of Eggs						
			Observed		Adjusted		Standardized		
	A	L317	A	L317	A	L317	A	L317	Inbred
Ill. A	–	20.2	–	8.9	–	10.2	28.0	24.3	9.8
Ind. H22	22.2	–	19.4	–	14.6	–	34.8	–	17.0
Wis. W23	23.0	22.4	12.4	32.4	5.1	26.9	12.1	64.0	17.8
Ind. B2	21.0	19.7	13.5	13.6	12.3	16.4	14.4	29.3	24.8
Ill. R4	22.5	22.4	14.2	21.9	8.4	16.4	20.0	39.0	24.9
Ia. L289	22.2	20.7	13.6	14.4	8.8	14.2	21.0	33.8	25.6
N.J. A47	23.3	21.8	8.2	28.3	.1	24.7	.2	58.8	27.8
Kans. K55	20.0	17.8	9.6	11.9	11.5	20.6	27.4	49.0	30.4
Ind. 66 (3709B)	21.4	21.0	12.0	28.0	9.6	27.0	22.8	64.3	30.4
Ill. Hy	18.4	21.8	7.8	18.5	14.6	14.9	34.8	35.5	30.6
Ind. 33-16	22.0	19.7	17.4	13.2	17.0	15.1	31.4	40.5	30.7
Ind. H5	–	18.1	–	9.8	–	17.6	–	41.9	33.3
Kans. K4	20.3	20.4	3.8	21.0	4.8	21.7	11.4	51.7	34.4
Kans. K66	20.0	20.2	11.9	35.3	13.8	36.6	32.8	87.1	34.8
Kans. K64	16.8	18.0	4.4	8.4	16.2	16.5	38.6	39.3	36.7
Kans. K63	–	15.5	–	7.3	–	23.1	–	55.0	37.0
Ind. H21	21.8	20.4	14.8	29.4	11.2	30.1	26.7	71.7	38.5
Ill. 90	16.4	17.8	4.3	10.8	17.3	19.5	41.2	46.4	38.8
Mich. Ms1	22.7	21.4	25.6	27.4	19.4	25.0	46.2	59.5	38.9
Ill. Mi4	20.5	21.3	4.9	21.4	5.3	19.3	12.6	46.0	38.9
Wis. W26	23.3	21.4	20.4	21.5	12.2	19.1	29.0	45.5	39.2
Kans. K41	18.9	19.4	9.3	21.8	14.6	25.6	34.8	61.0	40.0
Ia. Os420	20.8	–	10.7	–	10.2	–	24.3	–	40.4
Ia. I234	18.6	18.5	5.8	12.2	12.0	18.7	28.6	44.5	40.7
Ind. P8	18.1	19.1	10.2	25.1	15.6	29.8	37.1	71.0	40.8
U.S. CI. 187-2	20.6	15.8	13.8	5.4	13.9	20.2	33.1	48.1	41.8
Ind. 38-11	21.8	22.1	27.6	27.6	9.5	23.1	22.6	55.0	42.1
N.J. B42	20.8	22.6	10.8	24.1	8.3	18.0	19.8	42.8	44.1
Kans. Kys	22.1	19.0	16.7	21.3	18.1	21.7	43.1	51.7	44.1
Ind. Tr	22.9	22.7	23.6	45.6	16.6	39.2	39.5	93.3	47.0
Ill. L	–	20.4	–	16.7	–	17.6	–	41.9	47.4
Mo. 940	20.0	20.2	3.8	22.0	5.7	23.3	13.6	55.5	49.2
Ill. R30	16.0	16.8	8.1	15.2	18.4	22.3	43.8	53.1	49.2
Ia. Pr	17.9	19.8	4.5	27.4	12.9	29.9	30.7	71.2	67.8
Kans. K44	18.3	19.4	4.3	19.5	11.5	23.3	27.4	55.5	71.8
N.J. A64	19.6	20.8	6.1	39.4	9.3	38.9	22.1	92.6	73.3
Ill. R7	18.4	17.7	8.9	10.1	15.7	19.1	37.4	45.5	82.2
Ia. Ldg	–	13.2	–	0.	–	22.8	–	54.3	82.6
Kans. K155	21.8	20.7	7.9	20.3	4.3	20.1	10.2	47.8	–
Ohio 51A	19.5	21.1	7.8	16.2	11.3	14.7	26.9	35.0	–
Ind. H23	17.4	16.6	8.0	4.8	17.9	17.2	42.6	40.9	–
Ia. Os426	20.9	19.6	11.5	25.9	10.7	19.9	25.5	69.3	–
L.S.D. 19:1	2.0	2.0	14.6	14.6	13.3	13.3	31.7	31.7	–

1946 Single-Cross Tests on Common Parent Inbred Lines

In another single-cross experiment, 41 inbred lines were tested in combination with low attractive inbred line Ill. A and high attractive inbred line Ia. L317. With few exceptions both crosses were represented in these studies (Table 6).

All crosses with Ill. A, with one exception, were less attractive than the companion cross with Ia. L317. There were statistically highly significant differences among the entries, both for average height at mid-oviposition as well as the number of eggs laid per plant. In addition, a breakdown of the variance of the number of eggs laid per plant among the single-crosses indicated that there were highly significant differences between an inbred cross with Ill. A and the companion inbred cross with Ia. L317 and also among the single-crosses containing Ill. A and those containing Ia. L317. There was a highly significant correlation between the number of eggs laid per plant and the height of the corn at mid-oviposition.

Among the single-crosses with Ill. A, New Jersey A47 x Ill. A received highly significant fewer eggs and Wis. W23 x Ill. A and Kansas K4 x Ill. A received significantly fewer eggs than the average of all the crosses with Ill. A. Two single-crosses, Michigan Ms1 x Ill. A and Ia. L317 x Ill. A, were significantly more attractive than the average of all the crosses with Ill. A.

Among the crosses with Ia. L317, Kansas K66 x Ia. L317 was significantly more attractive and Ind. Tr x Ia. L317 and New Jersey A64 x Ia. L317 were highly significantly more attractive than the average of all the Ia. L317 crosses. None of these single-crosses were significantly less attractive.

In Figure 1, the data from these paired single-crosses are plotted with the regression lines based on the relation of the single-crosses with low attractive Ill. A as a common parent, a second with the single-crosses with high attractive Ia. L317 as a common parent, and a third the general regression line based on the averages of those single-crosses where the inbred line was crossed on both Ill. A and Ia. L317. All the crosses with Ill. A were below the regression line based on the Ia. L317 crosses, indicating that all the Ill. A crosses were less attractive than the average of the Ia. L317 crosses. Only 4 crosses on Ill. A were above the general regression line. Of the crosses on Ill. A, 14 were between the general line and the regression line based on the crosses on Ill. A, and 17 were below the low attractive regression line. Conversely, all the single-crosses with Ia. L317 were above the general regression line, 15 were between this line and the one based on all the crosses on Ia. L317, and 14 were above the high attractive regression line.

Since inbred line Ill. A was selected for its low attractiveness and Ia. L317 for its high attractiveness to corn borer moths, the distribution of the single-crosses around these regression lines constitutes strong evidence that these inbred lines transmit their differences in attractiveness into single-crosses in which they occur. It may be further reasoned that those single-crosses with Ia. L317 as a common parent that fell above the regression line based on all the Ia. L317 crosses and those on Ill. A that fell below the regression line based on all Ill. A crosses received from the non-recurrent parent line factors which augmented the high attractiveness and low attractiveness of the factors contributed by Ia. L317 and Ill. A, respectively.

A study of the distribution of the deviations of the crosses on Ill. A and those on Ia. L317 about their respective regression lines indicated that the positive and negative deviations were not associated with the low attractiveness or high attract iveness of the non-recurrent inbred lines.

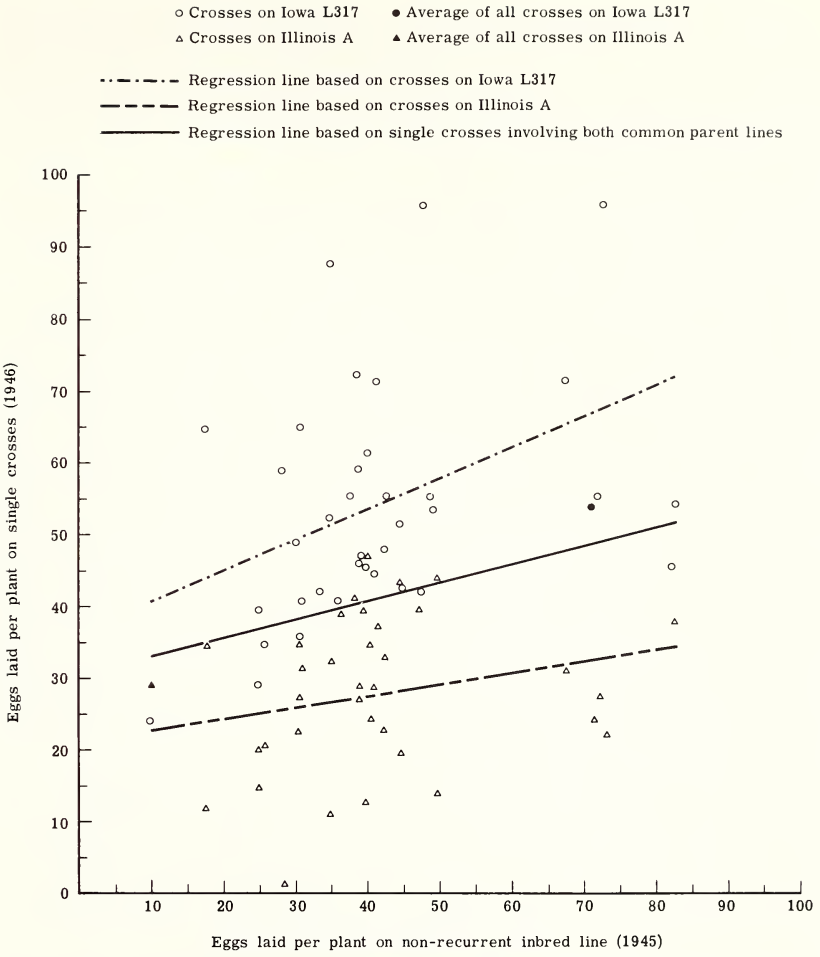
○ Crosses on Iowa L317
● Average of all crosses on Iowa L317
△ Crosses on Illinois A
▲ Average of all crosses on Illinois A
Regression line based on crosses on Iowa L317
Regression line based on crosses on Illinois A
Regression line based on single crosses involving both common parent lines
Eggs laid per plant on single crosses (1946)
Eggs laid per plant on non-recurrent inbred line (1945)
0
10
20
30
40
50
60
70
80
90
100

FIGURE 1. *Relationship of standardized number of eggs laid on single-crosses and number laid on the non-recurrent inbred lines. Lafayette, Indiana. 1946. (Table 7).*

Corn Genotypes Contribution to Single-Crosses

Although it has been demonstrated that wide differences exist in the number of eggs laid on different kinds of corn (1,4), practical use of such differences depending on evidence that the factors responsible for these differences in attractiveness are transmissible into single-cross combinations and are therefore available for genetic use. If the differences in attractiveness are controlled by genes in the genetic makeup of inbred lines, then there is the possibility of obtaining recombinations of these factors through breeding techniques. Such recombinations could result in the development of new inbred lines of extremely low attractiveness to corn borer moths, or inbred lines in present use could be reduced in attractiveness. This would result in hybrid corn for commercial production with less attractiveness to corn borer moths.

To analyze the relationship of the single-crosses used in the all-possible combination tests in 1944, 1945 and 1946, and the inbred lines comprising them, the inbred lines were assigned rankings based upon their attractiveness when tested as inbreds (4). The average number of eggs laid by corn borer moths on the inbred lines used in these all-possible single-cross studies and the relative rankings assigned them are given in Table 7.

Using these assigned rankings of the inbred lines for attractiveness, the single-crosses containing them were grouped into 9 classes based upon the combined total ranking of the inbreds comprising each single-cross. Thus, the single cross Ill. A x Ind. WF9 would have a rating of 1 plus 5 or 6 as an index of its potential attractiveness. Similarly, USDA CI.540 x Wis. W23 would have a rating of 6 (4 plus 2). After the 45 single-crosses tested in 1944, 1945 and 1946 were assigned to the classes representing their potential attractiveness, the number of eggs laid on them in each season, adjusted for height differences and standardized to a mean of 40 eggs per plant, were averaged. This was used as the best expression of the attractiveness of each particular class. To obtain a comparable figure on the number of eggs laid on the inbreds comprising the single-crosses in these classes, the number of eggs laid on each inbred as such was multiplied by the number of times each inbred occurred in the pedigress in each class and the total figure was divided by the number of inbreds involved. For example, to obtain the average performance of the inbred lines involved in the pedigress of the single-crosses occurring in class 10, inbred line USDA CI.540 occurred once, Ind. Tr twice and Ia. L317 three times. This gave a total of 46.8, the average number of eggs USDA CI.540 received as an inbred, plus 2 times 47.0 (94.0) for inbred line Ind. Tr, plus 3 times 71.0 (213.0) for Ia. L317 making a total of 353.8. Since there were 6 inbred lines involved in the 3 single-crosses in this group, this total was divided by 6 to obtain an average of 59.0, the potential number of eggs the inbred lines in these three single-crosses would have received (Table 8).

There was a highly significant correlation coefficient of 0.955 between the number of eggs laid on the single-crosses in each class and the inbred lines comprising them. Approximately 91.2 percent (R^2 x 100) of the variation in the number of eggs laid on the single-crosses can be accounted for by the number of eggs laid on the parent lines. When the data are plotted (Figure 2) the closeness of the data to the regression line indicates the high degree of assocation between the variables.

TABLE 7. *Rank of attractiveness to European corn borer moths of the inbred lines used in producing the combinations tested in 1944, 1945 and 1946. Lafayette, Indiana.*

Inbred Line	Average Number of Eggs Laid Per Plant*	Relative Attractive Rank
Illinois A	16.4	1
Wisconsin W23	17.9	2
Illinois R4	30.6	3
USDA CI.540	43.7	4
Indiana WF9	47.9	4
Indiana Tr	53.8	5
Iowa L317	64.8	6

*Data taken from tests as inbred lines (4).

TABLE 8. *Single-crosses tested in 1944, 1945 and 1946 arranged by classes based on the attractive indices of inbred lines comprising them, with the number of corn borer eggs laid per plant. Lafayette, Indiana.*

Pedigree of Single Classes	Attractive Class Index	No. of single Crosses In Class	No. of Eggs Laid Per Plant*	
			Inbred Lines	Single Crosses
Ill. A x Wis. W23	3	3	17.2	16.8
Ill. A x Ill. R4	4	3	23.5	32.1
Ill. A x CI.540 Ill. A x Ind. WF9 Wis. W23 x Ill. R4	5	7	28.5	26.0
Ill. A x Ind. Tr Wis. W23 x CI.540 Wis. W23 x Ind. WF9	6	6	33.3	28.2
Ill. A x Ia. L317 Wis. W23 x Ind. Tr Ill. R4 x CI.540 Ill. R4 x Ind. WF9	7	9	38.7	44.2
Wis. W23 x Ia. L317 Ill. R4 x Ind. Tr CI.540 x Ind. WF9	8	6	42.4	47.4
Ill. R4 x Ia. L317 Ind. Tr x Ind. WF9	9	5	49.0	48.0
CI.540 x Ia. L317 Ind. WF9 x Ia. L317	10	4	55.8	56.6
Ind. Tr x Ia. L317	11	2	59.3	59.3

*Adjusted for differences in plant height at 50 percent oviposition and standardized to a mean of 40 eggs per plant.

Also when the regression line calculated from the data is compared with the line that could be postulated if the attractive characters in the inbred lines were transmitted 100 percent into their single-cross combinations, it is readily apparent the difference was very small.

If we assume that there was a perfect relationship between the attractiveness of the inbred lines to European corn borer moths and the crosses comprised of these lines, then the regression equation would read $Y = X$, with a regression coefficient of 1.0. The regression coefficient based on the actual data is 0.966, with a standard error of 0.258. Comparing the data in Table 8 and the regression equation of $Y = X$, the standard error of the regression coefficient 1.0 is 0.443. The difference between the two regression coefficients is 0.034 ± 0.647, indicating that the regression coefficient based on the data, 0.966, did not differ significantly from 1.0.

From the foregoing comparison, it is readily apparent that inbred lines as a group transmit the qualities that affect their attractiveness to European corn borer moths to the single-crosses in which they occur. It is also apparent that the degree of attractiveness in the inbred lines is transmitted in a similar degree into

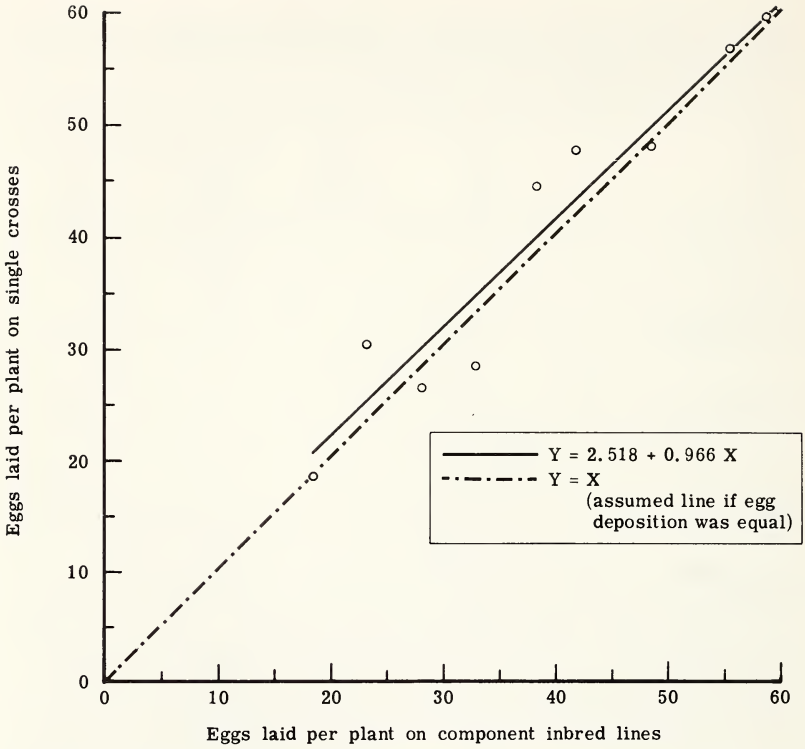

FIGURE 2. *Relation of number of eggs laid by European corn borer moths on single-cross hybrids to the number of eggs laid in the component inbred lines. Lafayette, Indiana. (Table 8).*

single-cross combinations of these inbred lines. Thus, the characters which influence the oviposition by corn borer moths on inbred lines of corn are genetic in nature and as such would lend themselves to breeding techniques.

Summary

Corn resistance to attack by the European corn borer has been categorized into 3 phases: attractiveness, antibiosis and tolerance (2). Tolerance has not been investigated although there is evidence that it may have an important effect in other host-insect relationships. Antibiosis has been under investigation for the past fifty years and significant differences in survival have been found. Antibiosis is most effective during the early stages of plant development. Distinct differences in genotype attractiveness have been recently reported (1,4). The data from these experiments clearly indicate that corn genotype attractiveness to ovipositing European corn borer moths is transmitted in a high degree to single-crosses and therefore is subject to genetic manipulation. In producing corn genotypes resistant to corn borer attack, the use of lower attractiveness has several advantages: (a) The differences in attractiveness are constant over the entire period of corn development; (b) Attractiveness becomes increasingly more effective as the level of oviposition increases; and (c) In the breeding program plants can be evaluated

for low attractiveness and used in the current breeding season. If low attractiveness can be combined with high antibiosis, losses from the European corn borer could be greatly reduced.

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Insects and other Arthropods of Economic Importance in Indiana During 1981

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The period from 1 October 1980 to 31 March 1981 was the driest 6 months in 100 years (Weather data summarized from "Indiana weekly weather and crops"). Lafayette, for instance, had only 6.7 inches of precipitation during that time. This facilitated soil preparation to the point that by 13 April, 90% of the plowing was completed. Growers had little opportunity to take advantage of the excellent soil conditions, for it started to rain and continued through May and far into June, slowing planting of both corn and soybeans. Some of the rains were heavy. Vincennes, for instance, received 15.27 inches of rain during May, its wettest month since record keeping began in 1889. By 10 June, when in average years all of the corn is planted, only about 70% was. The rains slowed planting least in the SW (southwest) district, followed by sections of the northern districts. The EC (east central) district, which has heavier soils, was most affected. In addition to losses due to late planting, to inundation and to flooding, late planting put many acres at risk to fall freezing temperatures, and some frosts occurred early enough to damage immature corn. Soybean planting was also delayed, but that crop suffered less than the corn because of the delay. And wheat, often lush in growth as a result of the plentiful moisture, suffered an abundance of diseases, the most conspicuous of these being powdery mildew.

With the exception of alfalfa insects, field crop insects were generally less abundant than in previous years. Some of this was due to the late planting, some to the direct effects of the weather. These will be discussed in connection with the various crops, where relevant.

Corns and Small Grains

A first-stage larva of the western corn rootworm (*Diabrotica virgifera*) was taken from soil samples collected 30 May in Tippecanoe (WC) Co., the first of the season. The first adult emerged in the same county on 2 July. In Knox (SW) Co., much further south, adults were common by 25 June. Peak adult emergence in Tippecanoe Co. occurred 21 July (cage studies). Sticky trap data from the same field follow; first adult: 6-8 July; half the season's catch was collected by 12 August, and peak flight occurred during the week ending 5 August. Total catch in 10 sticky traps from 6 July to 23 October was 10,606 (1977-1980 catches; 5,374, 5,938, 16,142, 2,329.) Sticky trap data for the northern corn rootworm (*D. longicornis*) in the same Tippecanoe Co. field: first adult during the week ending 15 July; half the total year's catch by 19 August with peak flight the same week. Total catch 1977-1981: 12,096, 2,513, 1,318, 479, 719.

Western corn rootworm adult numbers were down from last year. The state averaged 0.34 adults/stalk in a survey of 254 fields conducted between 27 July and 12 August, about half last year's average. Only 4 counties (Lake, Kosciusko, LaGrange and Noble) had averages as high as 1/stalk. In 1980, 2 districts had averages that high. The northern corn rootworm averaged 0.06 adults/stalk. While

some of the decline in the species may be attributed to egg dessication during the dry winter, a major cause of decline was the late planting.

Pupation among overwintering European corn borer (*Ostrinia nubilalis*) larvae in a Daviess (SW) Co. field of upright corn stalks occurred as follows: 20% by 21 April, 30% by 28 April, and 80% by 5 May. In Grant (C) Co., 70% had pupated by 12 May. Adults were taken at both ends of the state (black light traps) by 24 May. First generation flight peaked about 8 June, second generation about 9 August in LaGrange (NE) Co. at the Michigan border. Eggs and first generation first instar larvae were present in all central districts by 9 June. Because susceptible corn was scarce due to late planting, adult females had to concentrate on the few that were sufficiently mature. Thus, there were a few, widely scattered fields with heavy infestations of first generation larvae. Thirty inch corn is usually considered sufficiently mature to support borer larvae, but several instances of heavy infestations on 12-inch corn were reported.

Pupae from this generation were observed as early as 7 July in the southern districts, 10 July in the central. Adult flight was almost continuous from 24 May to the end of August at least in the NE district, and yet the state average of 22.6 live borers/100 stalks at the time of the fall survey was the lowest since the beginning of the survey in 1961. Two factors may have led to this result. Late planting resulted in a lot of susceptible corn, diluting the effects of the numbers of gravid females. Also, frequent and/or heavy rains are detrimental to early stage larvae. The highest district averages were in the NC and NE, peaking at 51 live larvae/100 stalks. In spite of low infestation rates, at the time of the fall survey 90 (out of 7,500 stalks surveyed) ears were already lost to the harvest as a result of borer-initiated stalk breakage or shank cutting.

In average years the black cutworm (*Agrotis ipsilon*) attacks late planted corn, especially in low areas with weed problems. Since corn planting was delayed so long this year, more problems with this species were expected. The first report came from Posey (SW) Co. It was unusual because it was so early (last week in April) and because of most larvae were late instar. Reports of damaged fields increased later, reaching a peak by mid-June. An estimated 1,000 acres suffered economic damage or needed treatment, primarily in the central districts. The first pheromone trap catch in Tippecanoe (WC) Co. was on 1 April. Light and pheromone trap data were inconclusive as to flight peaks.

There were 3 unusual corn pests reported during the growing season. There were 2-4 Japanese beetle (*Popillia japonica*) larvae/row foot, nearly mature, in a 40 acre field of grain corn in Daviess (SW) Co. about mid-May. This insect was more common than usual this year and often appeared in corn fields during time of silking. No economic damage was reported as a result of clipping, however. About 4% of the corn in a Dubois (SW) Co. field was attacked by larvae of a sod webworm (*Nomophila nearctica*) (Determined by D. M. Weisman, Systematic Entomology Laboratory, USDA). This is the first time in the last 15 years that this species has been identified from corn, although it is a common insect. Lastly, the common stalk borer (*Papaipema nebris*), not in itself unusual since it attacks border rows, but this year about a third of the plants in a 90 acre field of corn in Fulton (NC) Co. were attacked, and from 15-20% of the plants in a no-till field in Steuben (NE) Co.

Again because of delayed planting, ear tip feeding in corn by the corn earworm (*Helothis zea*) and the fall armyworm (*Spodoptera frugiperda*) was more common. About 9% of the 7500 plants seen during the fall corn insect survey had been attacked by 1 or the other of these species. At that time, of the larve still present in

the ears, 310 were corn earworms, 44 fall armyworms. Last year only 2% of the ears were attacked, and 88 larvae were present. Fall armyworm whorl attacks were unusually numerous in the SW district earlier.

About 4% of the ears had been attacked by birds.

Fifty to 80% of the WC, SW, and SC corn fields visited between 6 and 8 July had corn leaf aphids (*Rhopalosiphum maidis*); infested fields had about a fourth of the plants with colonies, mostly small. By the time of the fall corn insect survey (Sept.-Oct.), 30% of the 7500 plants seen had at least some aphids. A total of 14% of the 7500 had colonies large enough to blacken all or a portion of the tassel, as compared weith 6% the year before. Late planting probably contributed to the situation.

Two insects were involved with both corn and small grains. The oat bird-cherry aphid (*Rhopalosiphum padi*) was common on wheat in the SW and SC districts, less so in the central, by the end of April. A week later the populations had begun to dwindle. The mildewed condition of the wheat, fungus disease attacking the aphids, parasites and coccinellid predators probably all contributed to the reduction. The same species was present in 37% of the surveyed corn fields in the Sept.-Oct. survey, mostly in the northern districts. The insect seems to be more common in corn in fields with high plant populations or during wetter years. It was present in only 13% of the fields last year, a relatively dry year.

The other insect pest of both corn and small grains this year was the armyworm (*Pseudaletia unipuncta*). Centimeter-long larvae were reported as early as 5 May in Shelby (C) Co. in trace numbers. A corn field in Parke (WC) Co. had larvae up to 1 cm long on about half the plants by 20 May; larvae up to 2 cm could be obtained from roadsides all over the northern districts a week later. During the first week in June there were numerous reports of problems especially in no-till corn and in wheat; the latter was often lush in growth as a result of the abundant moisture. About 1000 acres, most of them wheat, required treatment for armyworm control. By mid June the problem virtually disappeared, the result of parasite activity. It was again in the NE district, as it was last year, that economically infested fields were most common.

Hessian fly (*Mayetiola destructor*) populations were up from last year, but in both resistant and non-resistant wheats nowhere nearly the 20% infestation rate considered economic. The mean infestation rate for all cultivars was 1.9%, nearly twice that of last year. H_5 gene resistant cultivars averaged 2.0%, H_3, 1.6%. Only 3 of the surveyed fields had non-resistant strains, not enough for comparison purposes. Puparia/100 stems increased from 1.2 to 1.3. (The survey was conducted cooperatively by the Indiana Crop Improvement Association, the Agriculture Research Service of the USDA, and the Department of Entomology, Purdue, and involved 275 fields in 51 counties.

Forage Legumes and Soybeans

Blender extracted alfalfa weevil (*Hypera postica*) eggs in the SC district averaged 4/15 cm^2 on 24 February. 9 on 10 March, 10 on 23 March, 30 on 31 March and 50 on 7 April. Percent tip damage in the same district averaged (mean alfalfa height in cm in parentheses) trace (4) on 23 March, 9 (10) on 30 March, 22 (16) on 7 April and 64 (31) on 14 April. By 24 April, most SW fields visited had been treated, and most SC fields needed treatment as did many WC fields south of Indianapolis. A week later many EC fields south of Indianapolis were at economic levels. Except

for WC counties as far north as Fountain Co., a treatment for the alfalfa weevil north of Indianapolis was not necessary, or early cutting would have been a viable alternative.

The potato leafhopper (*Empoasca fabae*) was a persistent pest in alfalfa this year. Adults were present already before the first cutting. A LaPorte (NW) Co. alfalfa field was rated at 40 adults/100 sweeps as of 10 May, for example. The first cutting probably received no pesticide for the potato leafhopper, but all subsequent cuttings over much if not all of the state suffered severe damage if left untreated. (There are about 425,000 acres of alfalfa in the state.) Only 1 field was observed in which the regrowth following the first cutting was delayed by larvae of the variegated cutworm (*Peridroma saucia*), which were present in alfalfa fields, but as a rule did no noticeable damage. Eggs were first observed on 7 April, in Harrison (SC) Co.

The first Mexican bean beetle (*Epilachna varivestis*) adult of the season was collected from Union (EC) Co. alfalfa on 30 April, about the usual time for the species. The first eggs on trap crop snap beans were deposited 29 May, and adults were present on Parke (WC) Co. soybeans at that time. The 20th of June marked the beginning of the first generation, i.e., the most common stages on soybeans through most its range were eggs and small larvae. By 8 July, half the larvae had pupated in the southern districts, and by 15 August new adults were present as well as pupae and late instars.

In the past the insect has been confined to Indiana south of Indianapolis on soybeans, with the exception of northward extensions on either side of the state: to Winchester on the east and Veedersburg on the west. Elsewhere in the northern half of the state perhaps 1 or 2 isolated spots are infested each year, populations which do not usually reappear the next year. This year the isolated spots were numerous, and reached the Michigan border, including sightings in LaGrange, Whitley (several fields), Huntington (several fields) (NE), St. Joseph and Wabash (NC) counties.

Late in the season there were scattered fields in Clay, Owen (WC), Bartholomew (C), Union (EC) and Franklin (SE) counties with economic infestations, especially in maturity group 4 soybeans. An estimated 50,000 acres were treated, but only a small portion of that acreage needed it.

Bean leaf beetle (*Cerotoma trifurcata*) adults were collected as early as 15 April from alfalfa in Vigo (WC) and Sullivan (SW) counties. WC alfalfa fields often harbored large numbers—sometimes in excess of 1/sweep. Economic infestations feeding on soybean leaves occurred last year, and with such numbers so early in alfalfa problems were anticipated, but none was observed. Soybean root feeding by the larvae was not reported, although it might well have been present.

The green cloverworm (*Plathypena scabra*) was present through the season, rarely even approaching economic numbers, until about mid-August. It then virtually disappeared from soybeans as a result of disease and parasitism.

A leafminer (*Odontota horni*) was rarely numerous in a single Jasper (NW) Co. field of soybeans last year. Only trace numbers were in the vicinity this year, but adults were collected (in trace numbers) from the NW county of Benton, the NC counties of Elkhart, Fulton and St. Joseph, and the NE county of Whitley. In some instances the adults were reared from pupae within mines.

Ornamentals Forest, Shade and Fruit Trees

Data concerning fruit trees have been provided by Thomas Mouzin (USDA,

Vincennes), and are based on pheromone trap catches. Codling moth (*Cydia pomonella*) flight was about double that of last year, with a heavy flight from the end of April to mid-June and another from mid-July to mid-September. Oriental fruit moth (*Grapholitha molesta*) catches were 1.5 times those of 1980, with peaks about 1 May, mid-June, mid-July and all of September. Obliquebanded leafroller (*Choristoneura rosaceana*) flights were as last year abundant, with a peak flight the last week of May and a lesser flight from 7-27 September. Redbanded leafroller (*Argyrotaenia velutinana*) numbers were half those of last year, with large flights through most of April, the first half of June and most of September. Lesser peachtree borer (*Synanthedon pictipes*) numbers cannot be compared with those of the previous year, when live females were used as pheromone sources. This year synthetic substances were used. Peak flights were in early June and early September.

New county records for gypsy moth (*Lymantria dispar*) as detected in pheromone traps include LaPorte (NW), Tippecanoe (WC), Bartholomew and Boone (C). The first catch of the season: 6 July in Vigo (WC) Co.

First sod webworm catches in blacklight traps in W. Lafayette (Tippecanoe (WC) Co.): *Pediasia trisectus* 20 May; *Crambus mutabilis* 26 May; bluegrass webworm (*Crambus teterrellus*) 19 May.

Japanese beetles (*Popillia japonica*) effected severe damage to ornamentals over a wide area, especially in Indianapolis and Terre Haute. Likewise, the northern masked chafer (*Cyclocephala borealis*) was a wide-spread pest in both home and commercial turf. A Vermillion (WC) Co. football field was ruined by the larvae.

Man and Animals

First deer fly catches: *Chrysops niger*, 22 May in Tippecanoe (WC) and Harrison (SC) Counties; *C. callidus* and *C. cincticornis*, 2 June in Jackson (SC) Co.; *C. pikei*, 9 June, Johnson (C) and Union (EC) counties; *C. macquarti*, 9 June, Fayette (EC) Co. None of these catches falls outside published ranges.

Aedes vexans, the most commonly collected mosquito in a New Jersey mosquito trap in W. Lafayette (Tippecanoe Co.-WC), peaked in numbers in early June, late June and mid-September, but was present from mid-May to mid-October.

Beneficial Insects

Parasites played a conspicuous part in the control of at least 2 insects that might otherwise have become serious pests. Armyworm (*Pseudaletia unipuncta*) larvae were common especially in the NE district, and had effected damage to both wheat and no-till corn at scattered locations. By mid-June the cocoon masses of an undetermined parasite were abundant; in an Adams (NE) Co. field masses were counted at the rate of 1/30 cm^2, the highest level observed. The threat disappeared. The green cloverworm (*Plathypena scabra*) also began to build in soybeans, but by 25 August it had been replaced by the cocoons of *Protomicroplitis facetosa* and *Rogas nolophanae*, as well as diseased larvae attacked by *Nomuraea rileyi*. The few healthy larvae still present often bore evidence of attacks by the tachinid fly *Winthemia sinuata*.

Of 2,963 alfalfa weevil (*Hypera postica*) larvae collected between 13 April and 1 June and reared, 27% were parasitized by either *Bathyplectes anurus* or *B. curculionis*, the species appearing in about equal numbers, respectively (of the 27%) 14.2% and 12.6%. Of 730 from the northern districts 10% were parasitized, nearly all by *B. curculionis*. Of 891 from the southern districts 49% were parasitized, more

than 3 to 1 by *B. anurus*. The rate of parasitism did not change much over time in the WC district—the district most surveyed for parasites. Of 491 collected in April, 14.5% were parasitized. Of 488 collected in May, 15.2% were parasitized.

In order to speed the colonization of the northern half of the state by *B. anurus*, the USDA released that species in the following counties this year: Boone (C), Fulton (NC), LaPorte (NW), Lawrence (SC) and Wells (NE). The species has been slow in its spread following its initial release in Harrison (SC) Co. in 1965, Tippecanoe (WC) in 1967. It was first recovered in Harrison Co. in 1970, and has never been recovered from Tippecanoe Co. even though trace numbers have been collected as far north as LaPorte (NW) Co. (1980).

B. anurus was recovered this year from the following counties for the first time (The county name is followed in parentheses by the date of the collection of the host, and the city nearest the collection site. The author collected and identified the specimens). WC: Vigo (13 April, Prairieton). C: Shelby (19 May, Ray's Crossing). EC: Fayette (6 May, Glenwood), Union (6 May, Liberty), Wayne (6 May, Abington). SW: Knox (20 April, Emison).

Of 338 adult alfalfa weevils collected between 13 April and 26 May, 102, or 30.2% were parasitized by *Microctonus aethiopoides*. The parasite appeared in numbers by 13 April; last year no parasite was reared from weevils collected before 5 May. Only overwintering adults were tested. *M. aethiopoides* was recovered this year from the following counties for the first time (the county name is followed in parentheses by the date of the collection of the host, and the city nearest the collection site. The author collected and identified the specimens). NW: Newton (11 May, Kentland), Pulaski (12 May, Winamac). NC: Marshall (26 May, Donaldson), Miami (20 May, Peru) and Wabash (20 May, Lagro).

Another alfalfa weevil parasite, *Tetrastichus incertus* was released in Lawrence (SW) Co. this year, again by the USDA. It had been released at various locations in 1966, 1967 and 1968, but has never been recovered.

A single New Jersey mosquito trap suspended in the branches of a lone apple tree in West Lafayette, (Tippecanoe Co., WC) collected 1,387 adult specimens of the green lacewing, *Chrysopa rufilabris*, an arboreal species, in 1981. This is nearly double the previous high of 710 collected in 1978. The first adult was collected 17 May, the last 21 October.

Counts of some beneficial insects were made during the annual corn insect damage survey. This year 276 adult *Coleomegilla maculata* were observed, the highest since counts were began in 1975. The figure represents 96% of all species of beneficial coccinellids seen in the 300 fields. Counts were also made of the same species collected on 10 sticky traps at a height of 1 meter in a Tippecanoe (WC) Co. corn field from mid-June to mid-October. This year 300 were collected, down from the 318 of last year and peak of 407 in 1979. This was 71% of all of the coccinellids collected on these traps. The convergent lady beetle (*Hippodamia convergens*) was at its lowest level in the 5 years of this trapping—18—or 4%, while *Cycloneda sanguinea*, the small immaculate lady beetle, was at 107, or 25% of the total catch. No *Hippodamia tredecimpunctata*—the 13-spotted lady beetle—was collected this year.

Distribution of the Indiana Aeshnids (Odonata; Aeshnidae)

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Dragonflies of the family Aeshnidae are among the largest of the order, and except for a few moths are the largest insects found in this country.

Forty-two species distributed among 12 genera occur north of Mexico. Five genera, all of which are monotypical and three of which occur in Indiana, are Nearctic in distribution. Three are Neotropical but two of these extend into the Nearctic in the southwestern states or Florida. Two genera may be considered Cosmopolitan, another is circumtropical and one is Holarctic. Some species are very limited in distribution, others are widespread and one, the very common *Anax junius* (Drury), is found throughout North America from Alaska into Mexico and the Antilles, also in Hawaii and the eastern coast of Asia.

This study attempts to summarize the available date on the distribution of the Indiana species of this group of large and interesting insects. The six genera found in Indiana belong to four subfamilies—Aeshninae (Aeshna), Gomphaeschninae (Basiaeschna and Boyeria), Brachytrinae (Epiaeschna and Nasiaeschna) and Anactinae (Anax).

Any study of the distribution of insects reveals the inadequacy of our knowledge. Comparisons of faunae of different ares are usually based upon state lists. An examination of any such list shows that the data are very uneven; some forms are quite widespread and well-known and their exact range within a state quite well defined, others are included from a single record of a single specimen. As the limits of the ranges of species fluctate, the inclusion of species known from a small number of records at long intervals as a part of the fauna is questionable. The Odonata of Indiana were collected and recorded, both intensively and extensively for over 50 years (4). The seasonal distribution of the flight periods for all species were compiled by tabulation of the records of over 40 years, by thirds of months (indicated as I, II, III, respectively) (1).

The records which have been accumulated over such a long period of intense collecting have been used in this study to compare the aeshnid fauna of Indiana with those of other states. The records for other areas have been compiled over the years from state lists and other reports.

Many formulae for a quantitative expression of the relationship between faunae have been proposed. That by Preston (5) has been used previously for the Odonata of the North Central (2) and the Western (3) states. This formula is $\left(\frac{a}{a+b}\right)^z + \left(\frac{b}{a+b}\right)^z = 1$, where "a" is the fauna (in numbers) of one area, "b" that of the other, "a + b" the total number for the two areas, and "z" is an index of dissimilarity in percentage; similarity is obtained by subtracting the dissimilarity value from 100. The solution of the equation for the value of "z" is very difficult but Preston furnished a table from which this value can be read directly when the values of the two quantities have been calculated. A more simple measure of similarity may be computed by dividing the number of species common to both areas by the total number of taxa for both areas. This appears to be valid if the numbers in the two areas are approximately equal but not for cases in which the number in one area is much greater or less than that of the other. Both measures

comparing the fauna of Indiana with those of all other states and the provinces of Canada for which there are adequate records of the aeshnids have been computed and are given in Tables 1 and 2.

The known distribution within Indiana, the entire range and the extent of the flight period in the state (by thirds—I. II. III.—of months), respectively, are indicated for each species in the following list of genera and species.

TABLE 1. *Measures of similarity of the aeshnid fauna of Indiana with those of other states*

States	number of species		indices of similarity	
	recorded from state	common with Indiana	Preston's	direct percentage
Montana	2	0	0	0
New Mexico	3	0	0	0
Wyoming	4	0	0	0
Arizona	7	1	6	5
Colorado	8	1	7	5
Delaware	1	1	37	8
Oregon	6	1	9	6
South Dakota	1	1	33	8
California	12	2	12	9
Kansas	3	2	28	14
Utah	11	2	28	14
Arkansas	4	3	38	21
Nevada	9	3	23	16
Washington	8	3	23	17
West Virginia	3	3	23	23
Missouri	5	4	48	29
Nebraska	5	4	47	29
Georgia	11	5	31	26
Minnesota	6	5	53	36
Mississippi	8	5	43	31
Texas	8	5	42	31
D.C.	7	6	38	30
Florida	13	6	38	30
Kentucky	8	6	56	40
Rhode Island	6	6	75	46
Tennessee	7	6	59	43
Virginia	8	6	53	40
Alabama	9	7	58	47
Iowa	7	7	78	54
Louisiana	10	7	54	44
Oklahoma	9	7	58	47
South Carolina	9	7	58	47
Vermont	11	7	78	47
Illinois	8	8	82	62
North Carolina	13	8	67	44
Pennsylvania	13	8	67	44
Maine	14	10	66	59
Maryland	12	10	73	67
New Jersey	12	10	73	67
Wisconsin	11	10	78	71
Connecticut	12	11	84	79
Michigan	16	11	69	61
New Hampshire	17	11	69	61
Ohio	14	11	69	69
New York	16	12	72	71
Massachusetts	17	13	90	76

TABLE 2. *Measures of similarity of the aeshnid fauna of Indiana with those of the Canadian Provinces*

Provinces	number of species		indices of similarity	
	recorded from prov.	common with Indiana	Preston's	direct percentage
Yokon	5	1	9	6
Northwest Territory	7	1	9	5
Alberta	10	3	21	15
Prince Edward Island	3	3	41	23
New Brunswick	7	4	27	21
Saskachewan	9	4	37	25
Manitoba	10	4	27	21
British Columbia	18	5	27	19
Nova Scotia	15	9	55	47
Quebec	17	10	61	50
Ontario	20	12	71	57

Aeshna is a large cosmopolitan genus with 25 species and subspecies in the Nearctic and 35 in the Neotropical, three of which are common to the two regions.

A. canadensis Walker—Steuben Co.; Washington and British Columbia to the Maritime Provinces, south to Missouri and Maryland, but apparently not yet recorded in the states from Michigan, Wisconsin and Iowa to Montana; August II-III.

A. clepsydra Say—Steuben and Whitley Co.; Iowa and Wisconsin to the Maritime Provinces and New Jersey; August II to September I.

A. constricta Say—Tippecanoe to Wells and Steuben Co., British Columbia and California to the Maritime Provinces and Maryland, although unrecorded from all states from Idaho and Montana to Iowa and Wisconsin; July II to October I, most abundant in September.

A. mutata Hagen—Lagrange, Steuben, Noble and Wells Co.; southern Ontario, Massachussetts and Michigan to Pennsylvania, Indiana and Kentucky; June I to July II.

A. tuberculifera Walker—Lagrange Co.; Ontario, Wisconsin and Indiana to the Maritime Provinces and Pennsylvania, also British Columbia, but not recorded from the intervening territory; one record each in July II and September III.

A. umbrosa Walker—Probably throughout the state, recorded from 17 counties, chiefly Tippecanoe northeast, but also in Henry, Wayne and Lawrence; Yukon and Northwest Territory to Laborador and Newfoundland to Oklahoma and Alabama; July I to October I, most abundant in mid-September.

A. verticalis Hagen—Seven scattered counties in the northeast third of the state; Manitoba and Iowa to Maritime Provinces and North Carolina; July III to September III, most abundant in mid-September.

A. junius (Drury)—Common throughout the state; Alaska to the Maritime Provinces to Mexico and the Antillies, also Hawaii and the east coast of Asia; March I to October I; this species probably has the longest flight period of an odonate in Indiana.

A. longipes Hagen—Tippecanoe, Warrick, Dubois and Clark Co.; southern New England through all Atlantic and Gulf coastal states, through Mexico and the Antilles to Brazil, apparently only occasionally inland to Indiana; June and (?) July.

Boyeria is a Holarctic genus with two species in the eastern states and one in Europe.

B. vinosa (Say)—Throughout the state, recorded from 25 counties from the extreme southwest to the extreme northeast; Texas and the first tier of states west of the Mississippi northward to Iowa, to Ontario and the Maritime Provinces and Florida, recorded from almost every state within these limits; one record in May II, June III to October I.

Basiaeschna, Epiaeschna and Nasiaeschna are monobasic genera with almost identical ranges from Texas or Mexico north and east to Quebec and the Maritime Provinces and Florida, similar to the range of *B. vinosa*. As Indiana is within this area all three species—*B. janata* (Say), *E. heros* (Fabricius) and *N. pentacantha* (Rambur) are found throughout the state. *B. janata* is an early season flier, May I to July I, most abundant in mid-May. *N. pentacantha* is a mid-season form, June I to August III, with some breaks in the record. *E. heros* has a long flight period, March III to October I, with a few breaks in the record, exceeded only by Anax junius.

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A Possible "Resistance" to the Male Confusion Technique by Lesser Peachtree Borer Males

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Introduction

Chemical disruption of mating has been used with success against a variety of insect pests (5). The lesser peachtree borer (LPTB), *Synanthedon pictipes* (Grote and Robinson) has been shown to be susceptible to this type of control tactic (4). Much basic research, however, needs to be done on various biological aspects of mating disruption. Bartell and Lawrence (1) reported that low concentrations of pheromone in the atmosphere could cause habituation within the male, resulting in lack of response to calling females. Another factor operative with some species occurs when males are responsive, but a high background of pheromone in the area prohibits them from locating the point source represented by the calling female. Also, males may be attracted to artificial pheromone sources, thus diluting the numbers reaching the females; or in some species, both sexes may exhibit abnormal mating behavior where large concentrations of pheromone are present. These and other aspects of biology should be investigated for each species as disruptive tactics are developed.

This paper reports on results of experiments conducted to access the effect of (Z,Z)3,13-octadecadien-1-ol acetate (ZZ-ODDA) (6), the principal component of the sex pheromone of peachtree borer, *Synanthedon exitiosa* (Say), as a disruptant of lesser peachtree borer. It also reports on the unexpected reaction of laboratory reared males when released into areas treated with this material.

Materials and Methods

During the seasons of 1977, 1978 and 1979, observations were made of effects of ZZ-ODDA on distruption of mating of lesser peachtree borer. The test site was a portion of a commercial peach orchard near Patoka, IN, consisting of 10-12 yr. old Redskin peachtrees. The treated area of the orchard consisted of 135 trees in which a ZZ-ODDA pheromone disruptant lure supplied by Albany International Company was hung in the top of each tree. Each lure consisted of plastic capillary tubes open at one end and containing ca 15-20 mg of pheromone. One lure was used per tree, supposedly insuring a pheromone laden atmosphere throughout the treatment block. The untreated block was south of the treated block and consisted of a like number of trees. Prevailing winds were from the southwest to northeast. Five sticky traps containing 5 virgin females each were positioned within the 2 blocks to monitor male attraction. Lesser peachtree borer were reared in the laboratory on immature applies (2,3). Males were collected and marked with fluorescent pigments (7). In 1977 and 1978, such males were released into a peach orchard. In 1978, a series of experiments were initiated using caged trees to better assess the male behavior. During 1978 and 1979, only one cage was used while 2 separate trees were caged for the 1980 and 1981 tests. Cages were made of wood and galvanized screen wire, 3.5 x 3.5 x 3.5 M square. The treatment consisted of 3 ZZ-ODDA dispensers hung in the top of the tree. Laboratory reared males were marked and released in the cage. Wild males, captured in a walk-in trap baited with virgin females were collected and also released in the cage. A sticky trap baited with 3

virgin females was placed in the tree canopy to monitor male response. Percentage recapture was recorded and results analyzed using a paired comparison test.

Results and Discussion

During the 3 yrs of observations of male LPTB capture on female baited traps, a substantial decrease in capture was noted within the treated area. Total male capture during the 3 test seasons was 94, 85 and 28 in the treated areas respectively. In the control area, 507, 1527 and 1411 were captured in 1977, 1978 and 1979 respectively. The percentage reduction in capture was 84.4, 94.7, and 98.1% for the 3 years, indicating that efficiency of the disruption technique apparently increased.

TABLE 1. *Numbers of laboratory reared lesser peachtree borer males released and recaptured in a peach orchard. Treated block contained one ZZ-ODDA dispenser per tree.*

	No. released in	No. recaptured in		
	Treated	Treated	Untreated	Total
1977	3081	1155 (37.5%)	460 (14.9%)	1615
1978	950	336 (35.4%)	147 (15.5%)	483
	Untreated			
1977	3740	223 (6%)	1942 (51.9%)	2165
1978	950	61 (6.4%)	302 (47.3%)	363
	Between Blocks			
1977	785	70 (8.9%)	212 (27%)	282

Results of the 1977 and 1978 releases of laboratory reared males are shown in Table 1. Those males released into the untreated block were mostly recaptured within that block, with only 10% of the 2165 recovered males moving into and being trapped in the treated area. Of the males released in the treated block, 72% of those recovered were recaptured there. In 1978, essentially the same thing occurred. Of the 483 males recaptured from the release into the treated block, 70% were trapped in the treated plot. Such results were contradictory to those expected so further tests were conducted in cages.

Table 2 presents the results of 4 seasons of such observations. The summation of these 4 seasons indicates that only 10% of the wild males released in treated cages were recaptured, while 44% of the laboratory reared males were recaptured. In untreated cages, 26% of wild and 48% of lab males were recaptured.

The cage experiments showed a.) that laboratory reared males were more responsive to the females calling in the cages, a greater percentage being captured than the wild males, b.) that there was no significant difference in the number of laboratory reared males attracted to females in a pheromone laden atmosphere or clean atmosphere, c.) that a significantly lesser number of wild males were captured in pheromone treated cages than in untreated cages and d.) that significantly greater numbers of lab males were trapped in treated cages than wild males while there was no significant difference between numbers captured in untreated cages.

According to these results gathered over a 4 yr period, the male confusion control technique, although very successful against feral LPTB males, and indeed, actually appearing to improve from season to season, was essentially unsuccessful

TABLE 2. *Recapture of laboratory reared and wild males after release into untreated tree cages. Treatment consisted of 3 ZZ-ODDA dispensers in tree. Means followed by the same letter are not significantly different at the 5% level.*

	Number released				Number recaptured			
	LAB		WILD		LAB		WILD	
	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated
1978[1]	250	125	250	125	121	91	20	34
1979[1]	546	135	407	125	273	50	57	50
1980[2]	450	450	159	159	240	263	15	30
1981[2]	890	890	180	180	312	366	11	39
Ave.	534	400	249	147	237[a]	193[a]	26[b]	38[c]

[1] 1 cage used with alternate treated and untreated tests conducted.

[2] 2 cages used, one with treatment, one untreated.

against males reared in the laboratory. At this time, we can only speculate on the biological basis for this phenomenon.

Under high density condition, short range stimulii may provide the chief mechanism for mate finding. Laboratory reared males may move around more and through short range stimuli, contact greater numbers of females than wild males do. This would also be true if the great numbers of males released overflooded the treatment area. This however, fails to account for the results in the cages, where equal numbers of laboratory and wild males were normally released.

It is also within the realm of possibility that laboratory reared males may have developed a type of "resistance" to confusion. They are reared in high numbers in close proximity, male to female. Mating occurs in rooms where a high level of pheromone is undoubtably present. Whether this may represent a genetic change or only a behavioral adaptation is also unknown. If such an adaptation could occur in the laboratory, how many generations will it take for males developing in orchards containing high levels of pheromone chemicals to also adapt to this new means of control? This is another aspect of biology that needs further research.

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The Effects of Striped Cucumber Beetle Larval Infestations and of Plastic Film with Trickle Irrigation on Yield of Butternut Squash

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Introduction

Butternut squash, *Cucurbita moschata*, has the potential to become a major vegetable crop for Southwestern Indiana if adequately promoted. The fruit can be prepared as a variety of main dishes or preserved as pie filling providing a high quality substitute for pumpkin. The nutritional value of baked butternut is equivalent to that of baked potato both having high concentrations of vitamin A, exceeding the daily minimum requirement in a 100 gm baked serving (2). The crop can be stored for an average of 50 days (4) allowing a marketing period of up to 140 days when plantings are made sequentially.

Consumer acceptance of squash is on the increase as evidenced by the growth of frozen summer squash sales during the last decade, but sales of butternut squash are currently not large enough to be reported in Agricultural Statistics (1).

Buternut squash grow well in Southwestern Indiana where growers have the general knowledge and equipment necessary to grow the crop due to the similarities between its production practices and those of the melon crop. Before the potential of butternut squash can be reached, the consumer must be educated on the use and nutritional value of the crop; research must be conducted to evaluate production practices, optimal storage procedures, and control measures for insects and diseases; and the growers must be convinced of the potential for marketing and informed of the most profitable production techniques.

Materials and Methods

Butternut squash, variety Waltham, was evaluated when grown on plastic mulch with trickle irrigation and when infested with striped cucumber beetle larvae *Acalymma vittatum*. A randomized complete block design with four replications was used to compare the four treatments: mulch and trickle-uninfested, mulch and trickle-infested, no mulch or irrigation-uninfested and no mulch or trickle-infested. Each treatment was applied to a 15.85 m (52 ft) ft row of plants spaced 1.73 m (68 in) apart in rows spaced 1.83 m (6ft) apart. One and one quarter mill, .9 m (36 in) wide, plastic mulch and 1.9 1/m (.5 GPM), Tri-Wall® drip irrigation hose (Chapin Watermatics, Inc.)[1] were applied together using a Mechanical Transplanter (Model 90) mulch applicator[1] on May 22, 1981. The squash was direct seeded by hand, 3 seeds per hill, on June 11 and covered with ½ cup of Jiffy-Plus to prevent crust formation. Seedlings were thinned to one per hill on June 19.

When the plants had three true leaves, June 26, they were infested with 500 striped cucumber beetle eggs per plant. The number of infested eggs per plant was chosen arbitrarily as we have no estimate of field population of either adults or eggs. The eggs were from a colony that had been reared in the lab for five generations on squash seedlings. The eggs were suspended in 10 ml of .25 percent agar

[1] Mention of a proprietary product in this paper does not constitute an endorsement of that product by the USDA.

solution (3). A finger was pressed into the soil adjacent to the plant stem to allow placement of the eggs in the root zone, the egg solution dispensed into the cavity, and the cavity covered with moist soil. Eggs were dispensed with a 10 ml tipping pipettor. Egg hatch occurred on June 27-28 with 85.5% of the eggs hatching.

The infestation happened to coincide with the driest period of the summer and thus with the first irrigation. Starting June 26, the plots received one hour of irrigation each day totalling 20,373 1/Hect (2178 G/A) of water. July 10 and weekly thereafter, 11-4-4 N,P,K fertilizer was applied at a rate of 46.77 1/Hect (5 G/A) through the irrigation water.

An application of Prefar combined with three cultivations were used to control weeds. Applications of Bravo were made on ten day intervals to control plant diseases. One application of sevin was made during mid-August to control insects. Vines were turned back into the rows weekly to separate the plots for yield evaluations.

A one time harvest was made September 22 to determine plot yields. All of the squash in each plot were gathered and each fruit weighed individually. The yield data were analysed and the treatments seperated using least significant differences.

Results

Butternut squash plants responded to plastic mulch and trickle irrigation by producing larger more luxurient foliage throughout the growing season. This response was noticeable prior to irrigation, however, the initiation of irrigation, during the summers only dry spell, produced a dramatic increase in foliage.

The seedlings responded to larval root feeding of the striped cucumber beetle by producing visibly smaller plants, both when grown on sand or irrigated mulch. The relative differences in plant size diminished as the season progressed, but at the end of the growing season noticeable differences still existed between infested and uninfested plants on mulch.

Three yield parameters, fruit/plant, weight/plant, and weight/fruit were considered in analysing the effects of cultural practice and of striped cucumber beetle larval infestation. The data for the three parameters are presented in Table 1. Plants grown on irrigated mulch produced significantly more fruit and total weight than plants grown without irrigated mulch. Plants grown on irrigated mulch produced significantly fewer fruit and total weight when infested with striped

TABLE 1. *Yield of butternut squash grown with plastic mulch and trickle irrigation and infested with larvae of the striped cucumber beetle*

	Treatment					
#	Plastic mulch	Trickle irrigation	SCB larval infestation	Fruit/ plant	Wt./ plant (g)	Wt./ fruit (g)
01	No	No	No	3.89	6447	1312
02	No	No	Yes	4.54	6084	1339
02	Yes	Yes	No	8.95	12076	1353
04	Yes	Yes	Yes	6.68	9670	1448
LSD				0.40	607	NS

cucumber beetle larvae. Larval infestation did not significantly effect yield of plants grown without irrigated mulch. Neither irrigated mulch or larval infestation effected average fruit weight.

Discussion

Larval infestation by root feeding striped cucumber beetle larvae caused a reduction of 1.8 tons or $540. per acre. Larval infestations did not significantly reduce yield of plants grown on sand, probably because the infestation coincided with a period of considerable moisture stress. We have observed in the lab that larval survival is affected adversely by dry soil environment long before the squash plants begin to wilt.

The results of this research are drawn from a single season, but irrigated mulch appears to have considerable potential. Rainfall during 1981 was typical of most years in Southwestern Indiana where periods of overabundance are interspersed with dry periods.

Larvae of the striped cucumber beetle apparently benefit from the change in the soil climate caused by the trickle irrigated plastic mulch. The adult striped cucumber beetle has historically been considered a pest of cucurbits but the effect of larval root feeding has never been evaluated. The larvae have the potential to be serious pests of butternut squash and probably of most other cucurbit crops as well.

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Indiana State Records and Notes on Some Rare and Endangered Lepidoptera in the State (1972-1980)

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Superfamily Hesperioidea

Family Hesperiidae

Erynnis funeralis Scudder & Burgess—Funeral Dusky Wing

July 1, 1975 I collected one male *funeralis* in the Pigeon River State Fish and Game Area, Monogo, LaGrange Co. This essentially western species was identified by Dr. John M. Burns, Associate Curator of Entomology, National Museum of Natural History, Smithsonian Institution, Washington, D.C., where the specimen is deposited. *Funeralis* is the only Indiana *Erynnis* having distinct white fringes on the borders of the hind wings. It is a state record (8) (9).

Superfamily Papilionoidea

Family Lycaenidae

Epidemia dorcas (W. Kirby)—Dorcas Copper

Although I have been collecting a few *dorcas* each year, it has been only in the past two years that large colonies of them have been found. Dr. David Eiler of Manchester College and I found the first large colony on July 20, 1979 in the tamarack bog, Mongo, LaGrange Co. Dorcas, by the hundreds, were present on and near its larval foodplant, *Potentilla fruticosa* (11). July 14 and August 3, 1980 *dorcas* were widely distributed throughout the Pigeon River State Fish and Game area. July 26, 1980 more dorcas were found in the Binkley bog, Steuben Co. and in the Cedar Lake bog, LaGrange Co. Thus the survival of this one-brooded species in the state looks to be more encouraging.

Lycaeides melissa samuelis (Nabokov)—Karner Blue

In recent years there has been concern expressed for the survival of this species in Indiana. July 11, 1980 several dozen were observed, and only a few collected on a special permit in the Hoosier Prairie Preserve, Lake Co. Dr. Eiler photographed this lycaenid resting on its larval foodplant (*Lupinus perennis*), a plant not uncommon in the area. I concur with Dr. Jack R. Munsee of Terre Haute that the Karner Blue is an endangered species in Indiana; however, it is not uncommon in several areas of the United States.

Family Nymphalidae

Polygonia zephyrus Edwards—The Zephyr

September 1, 1975 I netted a perfect female of this rare western species 3½ miles east of Silver Lake and off Road 14 and the County Farm Road in a wooded area of southern Kosciusko Co. It was identified by Dr. Cyril dosPassos of the American Museum of Natural History, New York. In the United States the normal range of *zephyrus* is west of the Great Plains. It is a state record (8) (9).

Family Satyridae

Neonympha mitchelli (French)—Mitchell's Satyr

In the 1950s Mr. Homer Price of Payne, Ohio regularly found *mitchelli* on a

quaking bog on the east side of Cedar Lake, LaGrange Co. (3). On July 6, 1956 twenty-one fresh specimens were collected in the north bog, Cedar Lake. Likewise it has been found in Steuben Co.; however, I have been unable to find it in either county for the past ten or more years.

Mr. Lee Casebere, Assistant Director of the Indiana Division of Nature Preserves, gave me a damaged *mitchelli* which was captured with a handerchief on July 11, 1980 in the Cedar Lake bog. Concern for the survival of this endangered species in Indiana has increased because of recent land fills and the building of more cabins around Cedar Lake. Although the species seems to be holding its own in southern Michigan, habitat destruction may cause its extinction in Indiana.

HETEROCERA (Moths)

Superfamily Zygaenoidea

Family Megalopygidae

Lago crispata Packard—White Flannel Moth

July 7, 1980 I collected one in the Whitewater Memorial State Park, Union Co., and another July 9, 1980 Brown County State Park, both at black light. These are the first collected in the state (12).

Superfamily Geometroidae

Family Geometridae

Lytrosis unitaria (Herrich—Schaffer)

June 12 & 13, 1979 I collected three of these geometrids at light in the Brown County State Park. One was identified by Dr. Frederick H. Rindge of the American Museum of Natural History. When a 15-watt black light is placed on a white sheet covering the hood of an automobile, it attracks hundreds of moths and many obnoxious insect pests, which makes collecting sometimes uncomfortable. The specimen deposited in the American Museum is an Indiana state record (4) (11).

Lytrosis permagnaria (Packard)

July 13, 1979 I caught this very rare geometrid at black light, Silver Lake, Kosciusko Co. After Dr. Rindge had confirmed my tentative identification of the only specimen collected in Indiana, I agreed to deposit it in the American Museum (4) (11). This species is poorly represented in collections everywhere.

Lycia cognataria Guen'ee (= *Biston betularia cognataria*)—Pepper and Salt Moth

I first collected this interesting geometrid in the Brown County State Park on August 9, 1975 at the Nature Center's mercury vapor lamp; but, it was not until Dr. Rindge had identified my specimen netted on June 1, 1979 from the same park that I realized that it was an Indiana state record (5) (11). I now have both the light and the dark forms of *cognataria*, the species which provided an excellent example of industrial melanism in England.

Phigalia titea (P. Cramer)—Half-winged Geometer

August 5, 1979 I captured this species in the Brown County State Park at black light. It is a state record (5) (11). The 1980 summary report by the Indiana Department of Natural Resources states that it was also found in Jackson and Perry counties.

Cleora sublunaria (Guen'ee)

I collected this nondescript geometrid July 7, 1979 Silver Lake, Kosciusko Co.

August 8, 1979 Brown Co., and July 8, 1980 Brown Co.—all at black light. According to Dr. Frederick H. Rindge's distribution maps, this species has been found in Illinois and Kentucky but not in Indiana (6); therefore, it is probably a state record.

Xanthotype sospeta (Drury)

Sospeta is a diurnal and nocturnal species. During the daytime June 3, 1979 I captured several in a woods near Liberty, Indiana. June 4, 1979 one came to my black light located in the Whitewater Memorial State Park, Union Co. It is a state record (11). June 5, 1980 another specimen was collected at black light in the Whitewater Memorial State Park. Dr. Rindge's recent revision of the genus *Xanthotype* hass clarified the status of several species (7).

Superfamily Sphingoidea

Family Sphingidae

Lapara coniferarum (J.E. Smith)

July 8, 1978 I collected this hawkmoth in the Brown County State Park, at light. Generally it is more southern in its distribution. It is an Indiana state record (2) (11).

Sphinx franckii Neumoegen

On July 6-7, 1977 Dr. David Eiler and I captured this species at the mercury vapor lamps in the Brown County State Park, but it was not identified until the fall of 1980. Normally it is a rare resident species everywhere in the United States where it has been found—thus a record of unusual interest. Since then I have collected it July 7, 1978 and July 7, 1980, both in the Brown County State Park at light (12).

Superfamily Noctuoidea

Family Notodontidae

Hyperaeschra tortuosa Tepper

My first specimen was collected June 17, 1979 in the Brown County State Park. This rare species constitutes an Indiana state record (11). I captured another one June 21, 1980 in the city of Indianapolis, Marion Co. by using a black light.

Family Lymantriidae

Orygia definita Packard

June 18, 1979 one came to my black light placed near the Laketon tamarack bog, Wabash Co. This catch proved to be an Indiana state record (1) (11).

Leucoma salicis (Linnaeus)—Satin Moth

July 6, 1979 I took a single specimen at black light in the Brown County State Park. This delicately beautiful moth is an Indiana state record (1) (11).

Family Noctuidae

Spragueia dama Guen'ee

June 22, 1979 I collected *dama* in the Pigeon River State Fish and Game Area, Mongo, LaGrange Co. That night 42 species of moths were netted on the hood of my car which supported the black light. *Dama* is an Indiana state record (11). September 3, 1979 another one was captured with my small spiral net, near the edge of the Laketon tamarack bog, Wabash Co.

Metathorasa monetifera Guen'ee

During the day June 11, 1980 I collected two *monetifera* in the Hoosier Prairie Preserve, Lake Co. Waterproof boots and a special permit are essentials for collecting in this area. *Montifera* is an Indiana state record (12).

Family Arctiidae

Pygarctia abdominalis Grote—Orange-bodied Pygarctia

June 22, 1979 I collected this species with a black light, which was set near the boat landing area of the tamarack bog, Pigeon River State Fish and Game Area, LaGrange Co. It is an Indiana state record (11). July 8, 1980 I found it in the Brown County State Park and July 15, 1980 near the Laketon tamarack bog, Wabash Co.—both at black light.

Pygarctia spraguei Grote—Sprague's Pygarctia

Mr. Marc Minno, now a graduate student in Entomology, was the first to find this beautiful species in Indiana. He collected it May 30, 1978, Tippecanoe Co. (10).

I found one *spraguei* June 22, 1979 in the Pigeon River State Fish and Game Area, LaGrange Co., at black light (11).

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ENVIRONMENTAL QUALITY

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ABSTRACTS

Measurement of Pollutant Release from Sediments. WAYNE F. ECHELBERGER, JR., School of Public and Environmental Affairs, Indiana University, Indianapolis, Indiana 46223.——In recent years billions of dollars have been spent to reduce and eliminate water pollution, with some attention being given to the control of eutrophication in lakes and resevoirs. With regard to lake pollution, more information is needed concerning the measurement of pollutant release from sediment material. The intent of this research was the development of a relatively non-complex and rapid procedure for evaluating the release of inorganic and organic pollutants from sediments under anoxic conditions.

An electrolysis system composed of measuring instruments, direct current power source and reaction vessel was constructed for the experimental studies. Through the application of voltage and current, reduced conditions were maintained in the reaction vessel. The release of inorganic (ammonia-nitrogen and phosphorus) and organic (measured as chemical oxygen demand) pollutants was evaluated on sediments taken from: Stone Lake and Diamond Lake, Cassopolis, Michigan; St. Joseph Lake and St. Mary's Lake, Notre Dame, Indiana and the Cuyahoga River, Cleveland, Ohio.

It is felt that there are at least two methods of pollutant release from sediments to the overlying waters in lakes and reservoirs. These are diffusion of elements from the sediment water into the overlying water and consolidation which forces the interstitial water directly into the overlying water.

The results of this study indicated that the release of pollutants from limnological sediments is a function of the pollutant concentrations in the interstitial sediment water. The rate of ammonia-nitrogen release was found to be approximately three times that for phosphorus from sediments containing equal concentrations of ammonia-nitrogen and phosphorous. Based on the findings of this study, it would appear that the measurement of pollutant release from limnological sediments under anoxic conditions can be closely approximated by a determination of the specific pollutant concentrations in the interstitial sediment water.

Studies of Snow Acidification in the Indianapolis Indiana Metropolitian Area. MARY GARDNER and THAD GODISH, Department of Natural Resources, Ball State University, Muncie, Indiana 47306.——The effect of the Indianapolis area and associated sources of acidic atmospheric pollutants on the pH of snow was studied. Snow samples were collected along several transects of the metropolitan area immediately after six snow events during the winter of 1979-80. pH values were determined for each sample. In five of the six snow events, the pH of snow samples was observed to decrease along the direction of the wind as the storm passed over

the city. Ten to twenty miles downward, pH values were the same as those measured upwind of the city. For one snow event measured, pH values indicated that considerable acidification of snow occured before the snow reached the city, and a city-effect was not evident. Results of this study indicate that for most of the snow events studied, that pollutants emitted over the city were likely responsible for a slight decrease of snow pH.

The Natural Toxic Organics in the Aquatic Environment. ROBERT H. L. HOWE and JEAN M. HOWE, West Lafayette, Indiana 47906.——This paper discusses certain toxic organic compounds occurring in the aquatic environment due to natural processes. Some chemical pathways of their synthesis and degradation are presented.

Chamber Studies of Formaldehyde Emissions from Wood Products, Urea-formaldehyde Foam and Carpeting. BRIAN KANYER and THAD GODISH, Department of Natural Resources, Ball State University, Muncie, Indiana 47306.——Formaldehyde emissions from samples of major sources of indoor formaldehyde contamination were studied under laboratory conditions. Formaldehyde sources included particleboard, particleboard paneling, hardwood plywood paneling, urea-formaldehyde foam insulation and carpeting. All emission testing was conducted in modified dessicators using dynamic sampling procedures. Test conditions were controlled for temperature, relative humidity and ventilation rate. Formaldehyde concentrations were determined by using the Parosaniline Method. Initial studies focused on the effect of ventilation on chamber formaldehyde levels and source emission rates. Four ventilation rates 0.1, 0.5, 1 and 2 air changes per hour (ach) were employed for each source. Temperature and relative humidity were maintained at 20°C and 55% respectively. As expected chamber formaldehyde levels declined as ventilation increases. The effect of ventilation was most significant at low air change rates (0.1 to 1 ach). However, as ventilation increased the decline in chamber formaldehyde levels was partially counterbalanced by a significant increase of formaldehyde emission rates. The chamber studies indicate that ventilation as a formaldehyde abatement measure would be most effective under low residential air exchange conditions. These conditions are common during the fall and spring months and in energy efficient buildings. Studies were also conducted on the effect of various source combinations on chamber formaldehyde levels. When several sources were combined antagonistic effects were observed. These antagonistic effects may be due to the suppression of emissions from one source by another and/or one source may serve as a sink. Results from these source combination studies may have significant practical implications for the prescription of abatement measures to control indoor formaldehyde contamination.

Geochemical Characteristics of Coal Refuse Leachage. PATRICK J. SULLIVAN, Ball State University, Muncie, Indiana 47306.——Simulated geochemical weathering or coal refuse was conducted with the soxhlet weathering apparatus. Highly weathered coal refuse from Staunton, Illinois was continuously leached for up to 192 hours. Leachates were analyzed for pH, electrical conductivity, acidity, sulfate, iron, manganese, and aluminum. The results indicate that the soxhlet apparatus removed large amounts of metals and sulfate. Soxhlet weathering demonstrates that coal refuse contains soluble salts to degrade water quality immediately and reduced sulfur compounds that pose a potential long term acid problem.

Indiana State School Asbestos Program: A Status Report

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Introduction

Asbestos, the fibrous mineral silicate, has been known in its various forms and used for many purposes since prehistoric times. Establishment of its pathogenicity began in earnest in the 1920s and progressed until, throughout the 1960s and 1970s, the evidence of the correlation of asbestos with serious pulmonary diseases was assembled and given sufficient credibility to be convincing (5).

In addition to OSHA's concern about asbestos use in industry and the associated disease processes, the EPA became concerned with the disease causing potential of intermittent, low level exposures such as would occur in school buildings from asbestos containing materials. In this regard, the EPA has issued guidance outlines to school personnel to assist in establishing an asbestos control program (1). However, no federal funds have been available for sampling or analysis. The Indiana State Board of Health's Industrial Hygiene Division initiated a cooperative program with local health departments to determine the extent to which asbestos had been used in constructing Indiana schools.

Methods and Materials

Bulk samples of suspect materials were collected from schools in 92 counties by local sanitarians and sent to our lab. Samples were loaded into vials and test tubes in the hood for microscopic and x-ray analysis.

Polarized light microscopy (PLM) using dispersion staining was the primary identification technique. X-ray diffraction (XRD) analysis was used as a corroborative technique for determining the presence of asbestos. The theory and application of both analytical methods are well covered in the available references and will not be addressed in this limited space (4,7). Analyses were performed to determine qualitative asbestos content of bulk samples. In the case of XRD, the sample diffractograms were compared to standards generated by known asbestos samples (2).

The two methods of analysis complement one another. Unlike PLM, the x-ray cannot distinguish between fibrous and non-fibrous asbestiform minerals, the fibrous forms being of chief interest in the genesis of disease; and unlike XRD, the PLM is limited by size of fibers, which must be at least 0.5 microns in the smallest dimension (6). Figure 1 is a representative diffractogram of pure chrysotile asbestos mineral, the most prevalent form encountered in our survey. Figure 2 is a representative diffractogram of pure amosite asbestos, which is second in the quantity used commercially, and considered to be the more toxic of the two (9).

Results and Discussion

The Indiana counties that actively participated in our survey and the number of facilities sampled are listed in Table I. To date, 74 health departments have participated and 988 public buildings have been surveyed. The number of samples submitted ranged from a low of one per county to a high of 189. The variation in number of samples submitted was attributed to the personnel available and/or the

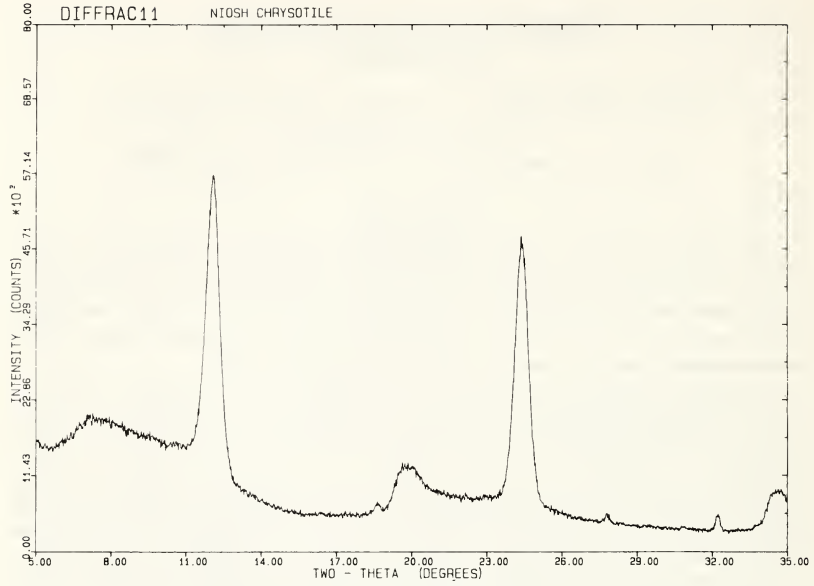

FIGURE 1. *Diffractogram of pure Chrysotile Asbestos*

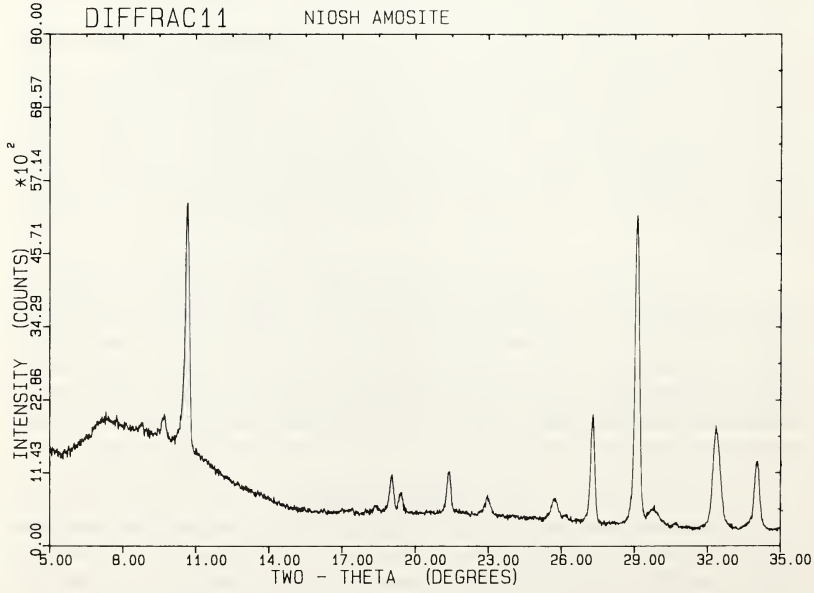

FIGURE 2. *Diffractogram of pure Amosite Asbestos*

TABLE I. *Counties Submitting Bulk Samples and Number of Positive Asbestos*

County	Number Buildings Sampled	Total Number Samples Submitted	Total Positive Microscopically	Total Positive by X-Ray
Adams	5	7	3	3
Allen	15	19	6	7
Bartholomew	17	46	17	9
Benton	7	17	7	9
Blackford	4	5	5	3
Boone	4	8	1	3
Brown	2	4	2	1
Carrol	1	5	1	1
Cass	10	14	8	9
Clark	23	26	9	5
Crawford	3	3	3	3
Daviess	1	1	1	1
Dearborn	9	19	9	10
Decatur	11	26	5	7
DeKalb	5	7	3	2
Delaware	41	174	55	59
Dubois	15	18	8	9
Elkhart	11	21	7	10
Fayette	2	4	2	2
Floyd	26	46	33	22
Fountain-Warren	4	8	5	4
Franklin	2	3	1	1
Grant	8	9	0	0
Greene	6	9	2	1
Hamilton	4	11	6	4
Hancock	2	3	0	1
Harrison	11	27	12	18
Hendricks	28	91	26	31
Henry	15	20	1	2
Howard	36	108	38	21
Huntington	18	35	9	12
Jackson	8	13	2	2
Jasper	4	9	2	2
Jay	10	20	1	1
Jefferson	7	33	11	9
Jennings	10	29	10	11
Johnson	8	8	6	6
Knox	3	3	2	2
Kosciusko	3	7	2	2
LaGrange	17	25	6	8
Lake	13	23	4	5
LaPorte	51	176	79	40
Madison	11	25	12	16
Marion	114	185	137	107
Marshall	2	4	1	1
Monroe	24	49	14	7
Montgomery	9	9	7	8
Morgan	4	10	3	3
Noble	6	6	6	6
Ohio	1	2	2	1
Orange	1	1	0	0
Owen	5	10	2	3
Perry	3	3	1	1
Pike	1	3	3	3
Porter	34	84	29	38
Pulaski	8	23	15	9
Randolph	6	42	11	11
Ripley	4	7	3	3

TABLE I. — Continued

County	Number Buildings Sampled	Total Number Samples Submitted	Total Positive Microscopically	Total Positive by X-Ray
Rush	2	5	3	5
St. Joseph	88	189	119	91
Shelby	23	59	19	13
Spencer	1	1	0	0
Starke	15	25	5	5
Steuben	9	24	7	8
Switzerland	5	10	1	2
Tippecanoe	8	11	2	3
Vanderburgh	16	23	1	1
Vigo	42	50	3	4
Warrick	18	56	9	14
Washington	12	33	9	6
Wayne	23	63	20	24
Wells	2	6	3	3
Whitley	15	81	10	21
Ball State Univ.	5	12	5	5
Taylor Univ.	1	2	1	2
Purdue	15	89	42	38

interest in performing a complete survey in that county. Other states (3,8) have reported that self-reporting surveys which rely upon the initiative of school officials to perform the asbestos surveys and samplying result in under reporting and incomplete responses to the program. Since Indiana did not have the resources available for a State administered and implemented program, the cooperation of the county health officers was encouraged using a uniform sampling and a hazard evaluation procedure such as the EPA guidelines (1) or the Ferris Index (9).

Microscopic analysis of the submitted samples showed 67.4 percent to contain identifiable asbestos fibers. The lower percent identified as positive by x-ray diffraction is due in part to sample preparation technique, sample matrix, impurity presence and percent of asbestos necessary to elicit enough counts to absolutely identify the crystal lattice patterns from the diffractogram.

County sanitarians were instructed to collect samples from areas using criteria such as traffic pattern, accessibility, water damage, friability, and condition. Air sampling was performed only at the request of the county sanitarian or school officials. Air samples were taken at seven schools in five different counties. Fiber counts ranged from 0.005 to 2.82 fibers per cubic centimeter of air. Using the OSHA regulation for asbestos fibers of 2.0 fibers per cubic centimeter of air, remedial action was suggested at concentrations over the OSHA limit.

Summary

Over 2,000 bulk samples have been analyzed by PLM and XRD for asbestos content. These results have been reported to county health offices and school officials. Air sampling has been performed in select areas where either school officials or county sanitarians have requested the services due to damage or planned renovation. Samples are still being received and analyzed and plans are being formulated to survey other public buildings in Indiana as resources allow.

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Macroinvertebrate Sampling and Water Quality Monitoring in Indiana

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Introduction

In 1977, the U.S. Environmental Protection Agency introduced its Basic Water Monitoring Program, which included a biological monitoring plan (15). This plan was designed to complement the states' ambient chemical monitoring programs by showing the effects of water quality on aquatic ife. In addition to existing phytoplankton and bacterial monitoring programs carried out by the states, an expanded biological monitoring program was proposed. A set of sampling stations (CORE Stations) was chosen to represent both polluted and unpolluted waters throughout the nation. Additional biological sampling at these fixed stations could then be correlated with the chemical data also collected there. Changes in water quality at these sites could thereby be more effectively monitored.

Since 1978, the Division of Water Pollution Control, Indiana State Board of Health has administered the expanded biological monitoring program in Indiana. Part of the program involves determinations of the abundance and composition of benthic macroinvertebrates in rivers. The community of macroinvertebrates in an aquatic ecosystem is very sensitive to stress, and its characteristics can often be used to detect environmental perturbations (e.g. 6). Because of the limited mobility and relatively long life spans of benthic macroinvertebrates, their community structure is a function of local environmental conditions during recent months. Macroinvertebrate sampling is especially useful in detecting infrequent perturbations that may not be discovered by periodic chemical sampling.

Macroinvertebrates were sampled in 1978, 1979, and 1980 at 19 CORE Stations in Indiana (Figure 1 and Table 1). The numbers and types of organisms pre-

TABLE 1. *CORE Station locations*

Stations	Name	Location	Period of Record
BD-0	Burn's Ditch at Portage	Lefty's Coho Landing	1979-80
EW-77	E. Fork White River at Williams	Williams Dam State Fishing Area	1979-80
IHC-1	Indiana Harbor Canal at E. Chicago	Dickey Road Bridge	1979-80
IWC-6.6	Indpls. Waterway Canal at Indianapolis	Confluence of Canal and White River	1978-80
KR-65	Kankakee River at the State Line	LaSalle Fish and Game Area	1978-80
KR-125	Kankakee River near Walkerton	Highway 104 Bridge	1980
M-95	Maumee River at Woodburn	Highway 101 Bridge	1979
SJR-46	St. Joseph River at South Bend	Auten Road Bridge	1979-80
SJR-78	St. Joseph River at Bristol	Town Park	1979-80
STJ-0	St. Joseph River at Fort Wayne	Tennessee Street Bridge	1979-80
TC-0.3	Trail Creek at Michigan City	Franklin Street Bridge	1978-80
WB-175	Wabash River west of Fairbanks	Breed Generating Station	1979-80
WB-207	Wabash River at Terre Haute	Fort Harrison Boat Club	1980
WB-292	Wabash River near Lafayette	Granville Bridge on CR 700W	1978-79
WB-301	Wabash River at Lafayette	Highway 26 Bridge	1979
WB-426	Wabash River at Bluffton	Highway 316 Bridge	1978-80
WR-48	White River at Petersburg	Highway 61 Bridge	1979-80
WR-205	W. Fork White River at Centerton	Henderson Ford Bridge	1978-79
WR-350	W. Fork White River near Winchester	U.S. Highway 27 Bridge	1979-80

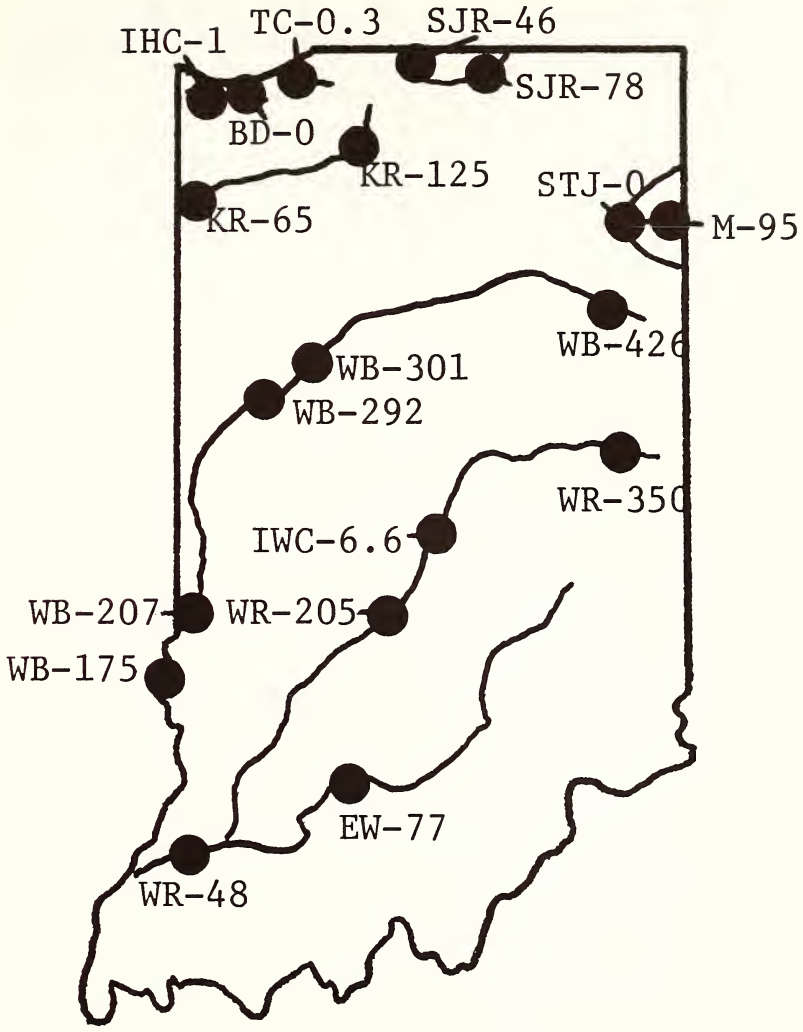

FIGURE 1. *Indiana CORE Stations.*

sent, species diversities, similarity coefficients, and community trophic structures were examined to provide indications of recent water quality at each site. Results were compared with chemical measurements of water quality published elsewhere (8, 9, 10).

Methods

Macroinvertebrates were collected on modified Hester-Dendy artificial substrate samplers (4). These samplers provide a standard substrate on which macroinvertebrates may colonize during a given exposure period. The confounding effects of substrate differences are thereby eliminated, so that data from different stations can be compared.

The samplers were either suspended from floats or tied to immovable objects within areas of permanent flow at a depth of 1 meter. Three samplers tied closely together were placed at each sampling location. Each year they were set out during late July or early August and recovered 4-6 weeks later.

After removal from the river, samplers were placed in trays with a small amount of water and disassembled. Each sampler plate and spacer was carefully scraped clean with a knife. The organisms and water were then poured over a U.S. Standard No. 30 sieve (0.595 mm openings), and the retained material was preserved in 70% N-propanol. Macroinvertebrates were sorted and identified to the lowest possible taxon in the laboratory.

The number of taxa present and their relative abundance were used to calculate the Shannon-Weaver Diversity Index (14) at each station during each year. Genus-level identifications were used for all groups except chironomids, which were identified only to family. Because identifications were not made to the species level, the computed index values are not comparable to those used by Wilhm (16) to classify water quality. Communities with average index values greater than 1.4 were considered to have high diversity, whereas average index values lower than 1.0 indicated low diversity communities, often associated with pollution-related stress.

The organisms collected were assigned to tolerant, facultative, and intolerant categories, according to their ability to survive in waters polluted by sewage. The presence of intolerant organisms at a station indicates waters with low concentrations of sewage-related pollutants. Organisms collected during this study that were considered pollution-intolerant are shown in Table 2.

An autotrophy index for each station was calculated by dividing the number of herbivorous individuals present by the total sample size. An abnormally large proportion of herbivores suggests that periphyton is abundant and often indicates nutrient-enriched waters (11). Chemical monitoring (8, 9, 10) showed that median nutrient concentratons at the CORE stations were about 2.5 mg/1 NO_3-N and 0.15 mg/1 total phosphorus. A t-test was used to determine whether herbivores were more abundant at stations with higher average nutrient concentrations.

TABLE 2. *Pollution-intolerant organisms collected during the study.*

Name	Reference
Plecoptera	1, 6
Trichoptera	
Macronema spp.	6, 13, 17
Brachycentrus spp.	5, 6, 17
Polycentropus spp.	1, 6
Ephemeroptera	
Stenonema interpunctatum	12, 13
Stenonema exiguum	1, 12
Ephemerella spp.	6, 17
Coleoptera	
Ancyronyx variegata	2, 6
Macronychus glabratus	2, 6

A Bray-Curtis Similarity Coefficient (3) was calculated for station pairs upstream and downstream from Fort Wayne, South Bend-Elkhart, Lafayette, Terre Haute and Indianapolis. This coefficient ranges between 0 and 1, so that sample pairs with a coefficient of 1 are identical and those with a coefficient of 0 have no similarities. Samples from each station pair should have high similarity coefficients if water quality is similar.

Results and Discussion

A summary of macroinvertebrate collections between 1978 and 1980 is given in Table 3. Macroinvertebrate samples at IHC-1, TC-0.3, BD-0, and WR-205 generally had low community diversities and never contained pollution-intolerant organisms. These stations had chronic low dissolved oxygen concentrations (< 5 ppm) and/or high total ammonia nitrogen concentrations (> 1 ppm) during the 3-year period (8, 9, 10). Macroinvertebrate communities at M-95 and WR-350 likewise appeared stressed, but chemical sampling did not corroborate this. Further study is needed to determine the source of stress at M-95. Unstable flows rather than unfavorable water quality may have been responsible for stressed communities at the headwater station WR-350, since small streams are far less stable than large ones (7). Though pollution-intolerant organisms were always collected at KR-65, community diversity was notably low there. The channelized nature of the whole Kankakee River watershed in Indiana may be responsible for this low diversity, since channelization greatly reduces macroinvertebrate habitat.

The effects of nutrient enrichment in rivers was also observed in macroinvertebrate communities. A high population density generally indicates some form of nutrient enrichment, either anthropogenic or by the natural enrichment occurring with increasing stream order (7). When average population densities at each station were subjected to a t-test, significantly higher ($p < .05$) densities existed at stations where average nutrient concentrations were greater than 2.5 mg/l NO_3-N and 0.15 mg/l total phosphorus (see Table 3). However, there was no significant difference in the percentage of herbivorous macroinvertebrates at these stations. Therefore, the autotrophy index could not be used to indicate nutrient enrichment.

Stations immediately upstream and downstream from Fort Wayne, South Bend-Elkhart, Lafayette, Terre Haute, and Indianapolis make it possible to evaluate the effects of these urban areas on macroinvertebrate communities. Bray-Curtis Similarity Coefficients for these station pairs are shown in Figure 2. Above and below Lafayette and Terre Haute, the samples were remarkably similar, suggesting that there was little effect from wastewater discharges in these areas. Samples downstream from Fort Wayne and Indianapolis, however, had lower community diversities, and pollution-intolerant organisms were always absent. Bray-Curtis Similarity Coefficients also show that the upstream-downstream communities were different. Pollution sources near these urban areas may have been responsible for the changes, especially at Indianapolis, where stressful conditions were chronic. An intermediate situation existed in the South Bend-Elkhart area, where pollution intolerant organisms were present downstream but community diversities were slightly lower and fewer taxa were present. Reasons for the low degree of similarity between upstream-downstream communities on the St. Joseph River are not clear, but may be related in part to flow variations caused by 2 hydroelectric dams between the sampling stations.

Water quality, as measured by macroinvertebrate response to stress and nutrient enrichment as well as by chemical sampling, was high at stations SJR-78,

TABLE 3. *Summary of macroinvertebrate collections, 1978-1980. Average values are computed from data for the period of record of each station (See Table 1). Symbols under "intolerant organisms" column are: A = always* absent, *P = always* present, *A/P = sometimes present. Stations marked with * had average nutrient concentrations greater than 2.5 mg/1 NO_3-N and 0.15 mg/1 total phosphorus (8, 9, 10).*

Sta.	Dominant family	Intolerant Organisms	No. of taxa		% herbivores		Diversity		No./sampler	
			average	range	average	range	average	range	average	range
BD-0	Chironomidae	A	5.7	4-7	5	0-8	0.90	0.13-1.45	96	12-289
EW-77	Hydropsychidae	P	10.1	8-11	23	11-30	1.57	1.36-1.82	664	489-1031
IHC-1	Tubificidae	A	1.8	0-5	0	0	0.01	0-0.03	450	0-1200
* IWC-6.6	Hydropsychidae Heptageniidae	A/P	9.9	7-12	36	19-56	1.47	1.07-2.04	726	78-1807
KR-65	Hydropsychidae	P	7.9	4-11	11	2-22	0.74	0.57-1.04	232	18-477
KR-125	Heptageniidae	P	7.3	5-9	66	63-88	1.11	0.98-1.20	79	71-93
* M-95	Heptageniidae	A	5.0	4-6	76	64-89	0.67	0.44-0.93	71	45-113
SJR-46	Chironomidae Hydropsychidae	A/P	7.3	5-9	3	1-4	1.00	0.59-1.47	620	202-1011
SJR-78	Hydropsychidae	A/P	9.7	6-13	9	3-15	1.47	1.00-1.78	1333	39-3026
STJ-0	Heptageniidae	A/P	6.7	5-10	60	28-77	1.06	0.76-1.30	221	108-384

TABLE 3.—Continued

Sta.	Dominant family	Intolerant Organisms	No. of taxa		% herbivores		Diversity		No./sampler	
			average	range	average	range	average	range	average	range
TC-0.3	Chironomidae	A	5.0	3-8	4	0-9	0.58	0.23-1.26	255	11-588
* WB-175	Hydropsychidae	A/P	8.8	7-9	12	9-14	1.43	1.32-1.56	1494	1041-2072
* WB-207	Hydropsychidae	P	8.0	7-9	11	11-12	1.35	1.31-1.40	1322	1111-1502
* WB-292	Hydropsychidae	P	9.0	7-10	10	7-15	1.29	1.16-1.51	1047	615-1656
* WB-301	Hydropsychidae	P	9.7	9-10	11	8-15	1.46	1.33-1.57	1800	1244-2188
* WB-426	Heptageniidae	A/P	10.3	6-13	35	13-69	1.38	1.01-1.56	359	93-626
* WR-48	Hydropsychidae	P	8.2	6-12	18	8-42	1.39	0.86-1.72	887	447-1567
* WR-205	Chironomidae	A	6.0	4-10	40	37-43	0.86	0.41-1.49	115	63-173
WR-350	Chironomidae	A	3.9	1-6	22	0-44	0.74	0-1.05	20	5-35

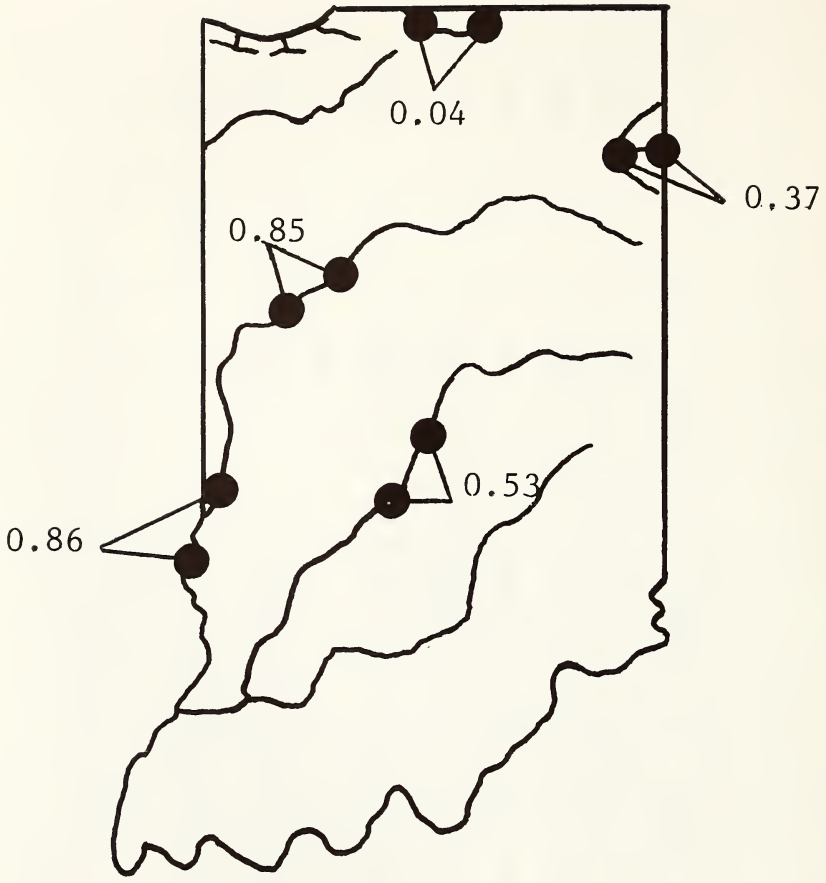

FIGURE 2. *Bray-Curtis Similarity Coefficients.*

KR-125, KR-65, and EW-77. Poor water quality was measured at IHC-1, BD-0, TC-0.3, M-95, and WR-205. Insufficient data exist to demonstrate whether water quality improved or deteriorated at any particular station during the period of study.

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Predictions by Computer Models of Downwind Effects from Instantaneous Releases of Toxic Gases[1]

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Introduction

Small towns located on rail or highway transportation routes, or which have chemical industry, oftentimes have a great deal of trouble dealing with the release of toxic gases. By the time they had contacted the shipper, the company responsible or local, state and federal officials to find out the nature of the hazard and what areas to evacuate, it is too late. Many times the general public has already been exposed to the toxic material.

Five computer programs have been developed which will help the appropriate officials to determine the following: 1) The concentration of the toxic gas at any point at any given time after the release. 2) Locates the toxic gas cloud at any given time after release. This program increments distance and gives the concentration of the gas at each downwind distance at a given time after release. 3) Calculate the shape and size and location of the toxic gas cloud at any given time after release. This program plots concentration isopleths. 4) Calculate the concentration with time as the toxic gas passes a fixed point. This could be used to determine the integrated dose that an individual would be exposed to if he did not evacuate. 5) The evacuation zone needed for public safety. This program plots an evacuation zone encompassing an area where the public will be exposed to a concentration that may cause bodily harm. This program also computes the arrival time of the toxic gas cloud and thus allows the determination of the time allowed for evacuation. A book of data including calculations for some common size gas releases and accompanying plastic templates have been developed which can be used with geological survey maps for a rapid determination of evacuation zones.

Equations of the Model

A model equation for the concentration produced at a given time and location downwind following an instantaneous release of a gas has been reported (2) and is expressed as

$$C = \frac{2Q}{(2\pi)^{\frac{3}{2}}\,\sigma_x\sigma_y\sigma_z}\,\mathrm{Exp}\left[-\frac{1}{2}\left(\frac{x-ut}{\sigma_x}\right)^2\right] \cdot \mathrm{Exp}\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]\mathrm{Exp}\left[-\frac{1}{2}\left(\frac{Y}{\sigma_y}\right)^2\right],$$

[1] The programs are written in the HP-Basic language for the Hewlett Packard 9830A computer equipped with plotter. A list of the programs can be obtained from the authors.

in which C (g/m^3) is the concentration at the surface at the location x(m) downwind from the release on the center line and y(m) lateral displacement perpendicular to the center line, H(m) is the vertical height at which the release occurs; σ_x, σ_y, σ_z (m) are dispersion coefficients referred to the horizontal x and y directions and the vertical z direction; Q (g) is the amount of the release; U (m/s) is the windspeed; and t(s) is the time interval following the release.

The dispersion coefficients σ_x, σ_y, and σ_z are in general complex functions of the weather conditions which are meteorologically classified by six weather stability categories, which are labeled as A through F from the most unstable to the most stable weather category. Weather stability category D is commonly regarded as an average condition which can be generally employed for estimations of the desired type where more detailed weather information is not available and was chosen to be employed as the basis for all of the computations carried out in this investigation.

In a previous paper (1) the authors reported the determination of low order functional approximations for horizontal and vertical dispersion coefficients to apply to a plume produced by a continuously emitting source for all six weather conditions. However, the data reported (2) indicated that these same dispersion coefficients would not apply to instantaneous releases. Values for σ_y and σ_z were reported for only two downwind distances from the source, and it was suggested that σ_x should be about the same as σ_y (2). It was regarded for this application that an adaptation of any of the previously determined approximations for any weather condition which would reasonably agree with the two specified values for weather condition D for both σ_y and σ_z would provide the most favorable estimation to apply to instantaneous releases. It was found that σ_y and σ_z to apply to an instantaneous release under weather condition D could be estimated by the σ_y and σ_z approximations for a continuous source under weather conditions F and E, respectively. The approximation for σ_y was also applied as the approximation for σ_x.

All of the computer programs developed were derived from the reported equation for the downwind concentration with the dispersion coefficients computed by the approximation stated above.

The Programs and their Applications

Program 1: This first basic program was developed to directly calculate the concentration at a specified position and time. This program is used to answer specific questions such as, "Is the emergency vehicle located at the corner of 1st Street and Chestnut Avenue being subjected to a dangerous concentration at this time?"

Program 2: This program developed as a modification of Program 1 will scan over a range of distance at a given time after the release. This program is used to locate the cloud as a variation of concentrations with distance at any given time. The program also has the capability of plotting the concentrations on a selected map scale. An example of the output of this program is presented in Table 1.

Program 3: This program was developed to locate and plot the isopleths or contours of constant concentration for a specified concentration using a range of distance previously determined from application of Program 2. The maximum concentration which can be employed is also obtained from the output of Program 2. This program is used to show the region in which the concentration will exceed a specified value or values. Several isopleths for differing concentrations can be overlaid in the same figure. Exemplary plots of a system of isopleths is shown in Figure 1.

Program 4: This program was developed to scan over time at a fixed position

TABLE I. *Variation of Concentration with Distance Amount Released, Q1 = 500 Pounds at Height, H1 = 10 feet or Wind Speed, U1 = 5 M.P.H. Time After Release = 30 Minutes.*

DWND DIST	CONC PPM
2.000	0.000
2.100	0.000
2.200	0.001
2.300	0.558
2.400	13.753
2.500	33.746
2.600	13,010
2.700	1.134
2.800	0.030
2.900	0.000
3.000	0.000

following the release. The concentration is computed with variation of time to indicate the exposure variation with time at that position. An example of the output

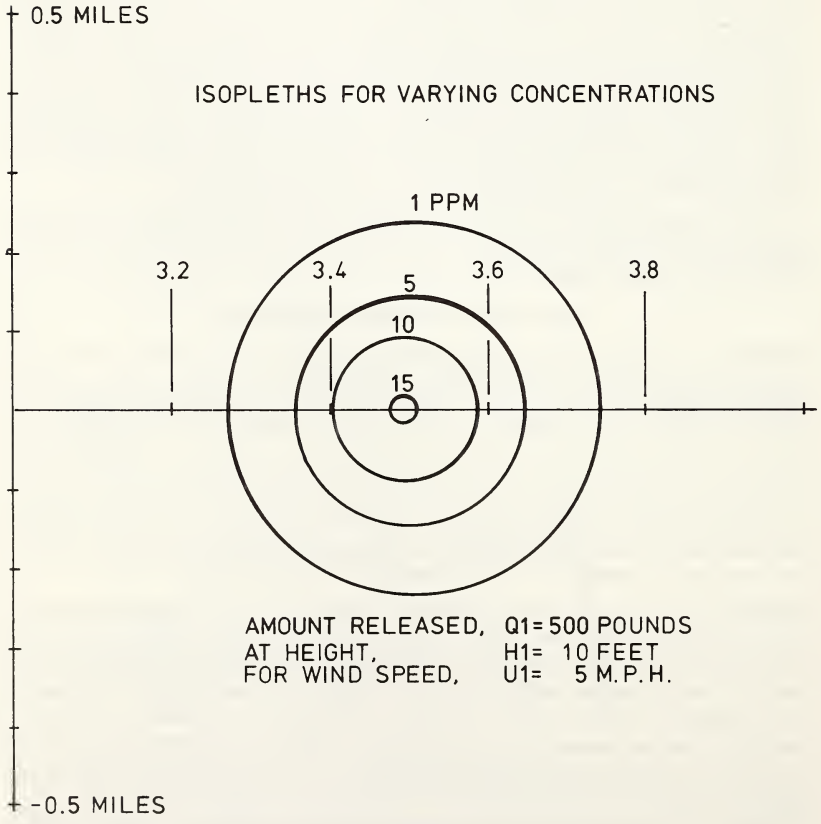

FIGURE 1.

TABLE II. *Variation of Exposure With Time at A Fixed Downwind Location. Amount Released, Q1 = 500 Pounds At Height, H1 = 10 feet for Wind Speed, U1 = 5 M.P.H. for Downwind Distance, X = 2.5 miles.*

TIME (MIN)	CONC (PPM)
27.000	0.11
28.000	2.59
29.000	17.77
30.000	33.75
31.000	17.77
32.000	2.60
33.000	0.11

of this program is shown in Table II. This output can be numerically integrated to yield a total exposure a person would encounter at a given location.

Program 5: This program was developed to determine and plot the envelope of the isopleths for a specified concentration but varied over a sequence of times. The region contained within the envelope is exposed at some time to a concentration above the specified value. Two or more envelopes for differing concentrations can be overlaid on the same figure. Exemplary Plots from this program are shown in Figure 2.

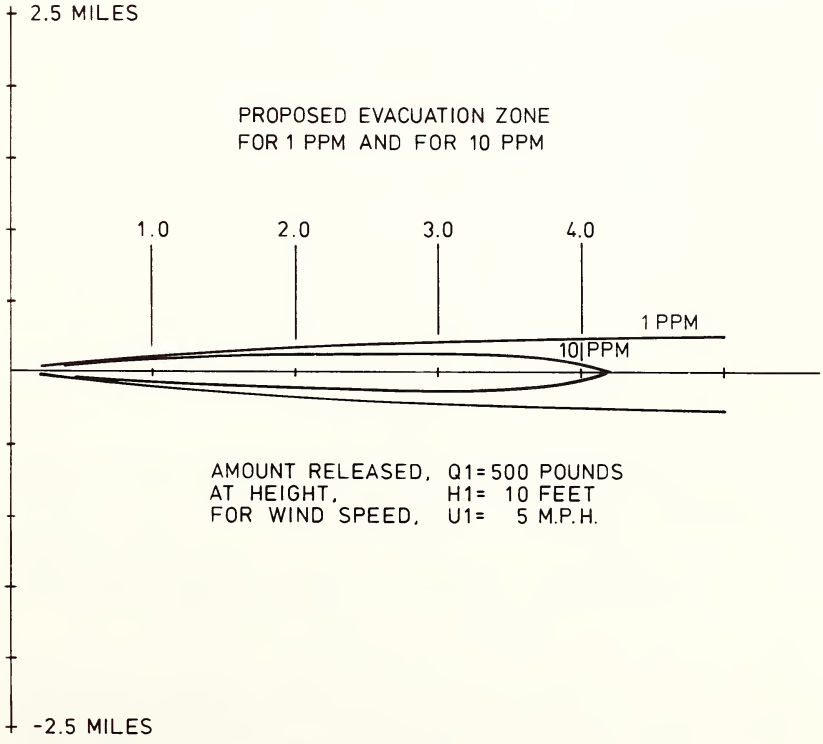

FIGURE 2.

This computer program has a great deal of practical utility. The output could aid authorities in rapidly assessing the area in which an imminent danger existed in the event of a toxic gas release or spill. It would allow them to get an idea of the urgency of the situation, and how much time they had to evacuate the people downwind from the source.

The program allows the user to pre-estimate the most likely size of a toxic gas release in his region, and to plot to scale the size of the downwind area that would be considered for evacuation. This isopleth envelope is drawn by the computer and can be permanently mounted on a plastic template or overlay. The authors have made some templates of this type to the same scale as found on Geological Survey maps. This was done so that the program would have the broadest applicability. With this information at hand an evacuation zone could be rapidly determined and the time allowed for such an evacuation could be obtained from a set of precalculated tables. The users of this information would have to know the following parameters: 1) the exact place and time of the toxic gas release, 2) the estimated size of the release, 3) the direction and velocity of the wind, 4) the height above the ground that the release took place. With this imput information, the program will calculate: 1) the downwind centerline concentration, P, in parts per million at downwind distance, X, in miles, 2) the arrival time, T, in minutes at downwind distance X, 3) and the lateral displacement, Y, in miles of the toxic gas cloud at some predesignated concentrations. An example of the tabulate output of this program is given in Table III.

TABLE III. *Evacuation Zone Data*
Amount Release, Q1 = 500 Pounds At Height, H1 = 10 Feet for Wind Speed, U1 = 5 M.P.H. Isopleth Envelope = 10 PPM

X(MI.)	T(MIN)	P(PPM)	Y(MI.)
0.500	6.000	1727.033	0.054
1.000	12.000	309.527	0.083
1.500	18.000	115.118	0.102
2.000	24.000	57.526	0.112
2.500	30.000	33.746	0.115
3.000	36.000	21.893	0.109
3.500	42.000	15.219	0.092
4.000	48.000	11.125	0.052
4.500	54.000	8.449	0.000

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Lead Contamination in Jasper, Indiana

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Introduction

The health hazards associated with working with lead have been recognized since the second century B.C. This knowledge, however, did not protect the slaves working in the mines in ancient Rome. In the 18th and 19th centuries, the increased widespread use of lead resulted in lead poisoning becoming a cause of ill health and death. Today the United States produces approximately a million tons of lead annually, which is about ten pounds per inhabitant. The majority of the lead is used in battery manufacture and for leaded gasoline production. The two largest sources of atmospheric lead emissions in the United States (2) in 1975 were from gasoline combustion, 127,800 tons (90.4%), and waste oil disposal, 5000 tons (3.5%). The contamination of roadside ecosystems from the combustion of leaded gasoline has been extensively studied and reviewed by William H. Smith (6) of Yale University. The size of this roadside ecosystem has been estimated to be 118,000 square miles. Lead in the upper 5 cm of the soil profile may be elevated 30 times non-roadside soil within a few meters of the street or highway. The soil lead is largely bound by organic matter or present as relatively insoluble lead sulfate.

In the late summer of 1980 it came to our attention that an inordinate amount of lead and other heavy metal contamination had been found in Jasper, Indiana (4). We were asked to determine the extent of contamination and the probable cause. The results of our preliminary investigation of the pH and lead content of water samples taken from the area caused a great deal of concern. This concern prompted a more extensive investigation of the lead content of sediment and soil samples and a survey of the extent of the contamination.

Description of the Study Area

The study area is located at the south edge of Jasper in Dubois County, Indiana. The area contains a mixture of industries and residential housing. Of particular concern was a low "swampy" area located east of Old U. S. 231 highway. The low area is adjacent to the back yards of several homes that are located along the highway. On the west side of Old U. S. 231, across from these homes, is an engine and transmission repair company which had a discharge that ran into a small ditch, went under the highway, and through a ditch which was at one end of a residential yard. A garden was located within about ten feet of this ditch. The local residents said that on occasion this ditch overflowed onto their garden. The ditch led to the "swampy" area described above. The low swampy area is wooded except for fairly large patches where there was no living vegetation. The low area drained into a creek and this creek flowed to the Patoka River.

The ditch and the low "swampy" area had a strong oily odor. On the trunks of the trees was a well defined oil ring. This ring was several feet above ground level, indicating that sometime during a high water situation there was a substantial amount of oil contamination. Some of the weeds were coated with oil and were dying. Some of the lower limbs of the trees were heavily coated with oil as the water receded. The sticks and stumps lying near the water's edge were also visually

coated with oil. There was an oily sheen on the water in some areas. The water in the swampy area had no visual sign of containing life.

Sample Preparation and Analytical Method

Water Sample Preparation: If the water samples were relatively free of suspended matter, they were run directly on a Perkin Elmer 401 Atomic Absorption Spectrophotometer. Samples that contained a substantial amount of sediment were filtered and then analyzed.

Soil and Sediment Sample Preparation: All glassware was extensively washed with hydrochloric acid and then rinsed several times with deionized water. The soil or sediment samples were placed on an acid-washed watch glass and oven-dried to a constant weight at about 105° C. A weighed portion of the dried sample was placed in a 250 ml. beaker and 100 ml. of concentrated HCl was added. The mixture was heated until about 20 to 25 ml. of solution remained. Twenty-five milliliters of water was added to the mixture and heated (not boiled) for 15 minutes. The solution was poured off into a separate beaker and the soil extracted twice more with water. The combined extract was then boiled to dryness. The residue was treated with 10 ml. of concentrated HCl and 10 to 20 drops of concentrated HNO_3. If any particulate matter remained, the solution was filtered. The resulting solution was diluted to 25 ml. and analyzed by atomic absorption spectroscopy. It was sometimes necessary to dilute the sample even more to fit into the working range of the calibration curve. Reagent and equipment blanks were run.

Results

An initial survey of the swampy area in Jasper, Indiana indicated that a rather severe pollution problem existed. Oil contamination was visually obvious. The pH of the ditch leading to the swamp as well as the water in the swamp was very high (pH 12-13). The initial laboratory analysis revealed lead levels in the water ranging from 15-69 p.p.m. or mg/liter. Barltrop has evidence that ingestion of as little as 1 mg/day by a 2-year-old child during a 6-month period will cause lead poisoning (1). Dr. Kehoe several years ago showed that normal adults ingest about 0.2 to 0.3 mg of lead/day, largely from foods and beverages, and estimated that ingestion of about 10 times that amount (2 or 3 mg/day) for a prolonged period of months would result in chronic toxicity (3). The finding of high levels of lead in the water prompted us to investigate soil and sediment samples.

Soil Analysis for Lead: The lead content of the upper layer of soils of unmineralized and uncontaminated areas is generally given as 10-20 p.p.m., dry weight basis (6). A sample taken from the top 5 cm. of soil along a Maryland highway that carried a traffic volume of 48,000 vehicles per day was found to contain 540 p.p.m. lead. We took a soil sample on high ground (not subject to flooding) and about 50 feet east of old highway 231, and it was found to contain 27-35 p.p.m. lead. The lead concentration varied with depth as shown in Table I. The soil in the garden ranged from 86-164 p.p.m. lead, which is from three to six times the concen-

TABLE I. *Lead Concentration In Soils With Depth*

Sample	Pb in ppm			
	0 - 1.5	1.5 - 3	3 - 4.5	4.5 - 6 in.
Near House	35	27		
Garden	98	86	130	164
Edge of Swamp	2820	742		

tration found in our background sample. The vertical distribution of lead concentrations in the soil samples taken from the garden indicated that the garden had been plowed. Soil samples taken near the swamp were very highly contaminated with lead. Lead levels as high as 2820 p.p.m. were found.

The lead contamination of the soil extends over at least 7.9 acres. The soil samples taken around the periphery of the swampy area contained lead at levels of 35-1094 p.p.m.

Sediment Analysis for Lead: Sediment taken from the ditch leading to the swamp contained 71 p.p.m. lead. Sediment taken from the ditch leading from the swamp contained 72 p.p.m. lead. Sediments taken from standing pools of water in the swamp had lead levels ranging from 2210 to 6643 p.p.m. Samples taken from underneath the railroad bridge that crosses the creek into which the swamp drains contained from 111-152 p.p.m. lead. It appears that in locations of fast-moving water, the sediments contained less lead than in standing pools or in areas of slow-moving water.

Figure 1 is a sketch of the area under investigation and contains a summary of the lead levels found in the water, soil, and sediment samples.

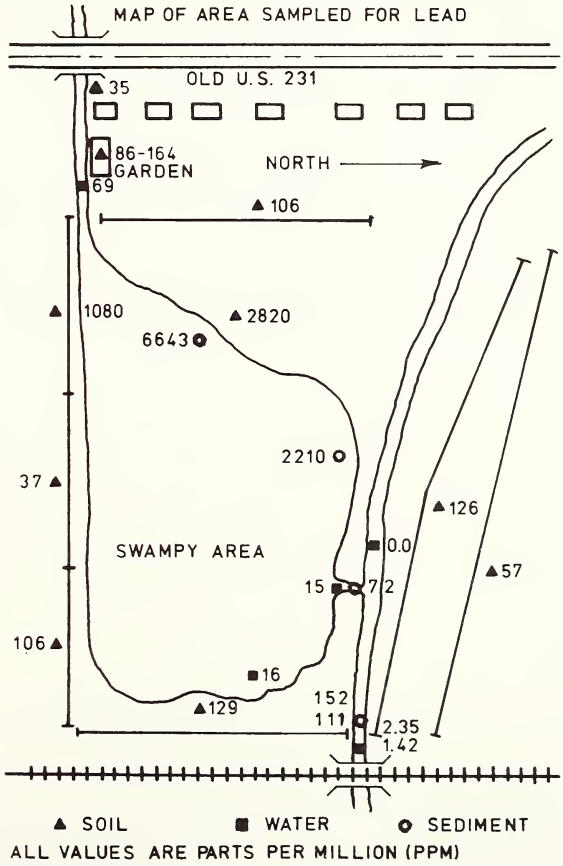

FIGURE 1.

Summary

The swampy area east of old U.S. Highway 231 and located at the south edge of Jasper, Indiana, has been found to be highly contaminated with lead. The water was also found to be very caustic and oil contamination was visually observed. One grab sample taken from the ditch leading to the swamp contained approximately 20% oil. The "water" sample burned when an ignited wooden match was placed into it. The lead contamination was observed in soil samples taken over an area of approximately 7.9 acres. There is every reason to believe that the soil and sediment contamination may extend well beyond the study area. It is the understanding of the authors that dredging operations are planned for the Patoka River. Since the Patoka River is the receiving stream for this drainage area, sediment samples should be collected and analyzed for lead before dredging operations commence. It would also be prudent to carefully assess the impact that a dredging operation would have, if any, on drinking water supplies located downstream.

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Chemical Analysis of Water Samples from Selected Tributaries of the Wabash River

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Introduction

Since there were limited data on the seasonal surface water qualities of streams near coal fields, this study was undertaken to show seasonally, the trends and effect of coal mining on the quality of surface water near coal fields. Samples were collected biweekly from five different sites. Two sites were near new mines and three sites were near old mines. These samples were analyzed for the concentrations of calcium, iron, lead, magnesium, manganese, potassium, and sodium cations; chloride, nitrate, and sulfate anions; and for physical properties like acidity, alkalinity, dissolved oxygen, pH value, temperature, and turbidity. The cations were analyzed using a Jarrell-Ash Atomic Absorption Spectrophotometer, while the anions were analyzed by titrimetric or colorimetric methods.

Experimental

Small tributaries of the Wabash River were sampled in Vigo County, Indiana. The streams were Coal Creek, Sugar Creek, and three tributaries of Honey Creek. Water samples were collected about a mile from the confluence of Coal Creek with the Wabash River. Samples from Sugar Creek were collected about three miles from the confluence with the Wabash River. Samples from the Honey Creek tributaries were collected about twelve to sixteen miles from the confluence with the Wabash River. Samples were taken twice a month from June 1979 to June 1980. Two of the sampling sites on Honey Creek were near new mines, and the third site was near an old mine. The sampling sites on Coal Creek and Sugar Creek were near old mines.

The analysis procedures used to assay the samples were performed according to standard methods (1,2). An atomic absorption spectrophotometer was used to determine concentrations of various cations in the samples. Five ml of nitric acid was added to a liter of water from the atomic absorption determinations. Selected anion concentrations were determined by titrimetric and colorimetric methods. Acidity was determined by titration of the sample with a standard base until a pH of 8.3 was attained. Alkalinity was determined by titration with a standard acid until a pH of 4.5 was attained. Dissolved oxygen, pH, temperature, and turbidity were measured with appropriate meters.

Results and Discussion

The maximum acidity concentrations for the samples collected near new mines for summer, autumn, winter and spring were 93.8, 22.0, 20.0 and 36.0 mg/l, respectively; and for samples taken near derelict mines the concentrations were 111.0, 230.0, 144.0 and 98.0 mg/l, respectively. The minimum concentrations found near new mines were 3.3, 8.0, 8.0 and 6.0; and 8.0, 10.0, 16.0 and 16.0 for the samples taken near derelict mines for summer, autumn, winter and spring, respectively. On the average, the concentrations near the new mines were 19.1 in summer compared with 13.1 in autumn, 13.3 in winter and 17.4 mg/l in spring; and near the derelict

mines the averages were 44.4, 54.3, 44.9 and 38.7 mg/l, respectively. The acidity was always greater in samples taken near abandoned mines than near new mines.

The maximum alkalinity concentrations for the samples collected near new mines were summer, 235.0; autumn, 206.0; winter, 226.0; and spring, 256.0 mg/l; while maximum concentrations for the samples taken near derelict mines were summer, 220.0; autumn, 196.0; winter, 190.0; and spring, 160.0 mg/l. The minimum concentrations found near new mines were summer, 45.0; compared with autumn, 56.0; winter, 44.0; and spring, 24.0 mg/l; while minimum concentrations in the samples taken near derelict mines were 16.0, 24.0, 48.0 and 50.0 mg/l for summer, autumn, winter and spring, respectively. For the samples taken near new mines the averages were summer, 121.1; autumn, 148.2; winter, 145.2; and spring, 150.1 mg/l; and average concentrations near derelict mines were 100.4, 102.7, 120.4 and 99.4 mg/l, respectively. The alkalinity was almost always greater in the samples taken near new mines than near abandoned mines, indicating that the acidity was more completely neutralized near the new mines.

It was found that the maximum calcium ion concentrations for the samples taken near new mines were summer, 300.0; autumn, 320.0; winter, 350.0; and spring, 250.0 mg/l; and the maximum concentrations in samples near derelict mines were 260.0, 240.0, 160.0 and 170.0 mg/l, respectively. The minimums for samples collected near new mines were summer, 35.0; autumn, 113.0; winter, 50.0; and spring 66.0 mg/l; while the minimums for samples near derelict mines were 53.0, 65.0, 50.0 and 25.0 mg/l, respectively. The averages near new mines were summer, 169.0; autumn, 214.0; winter, 207.0; and spring, 183.0 mg/l; while averages near derelict

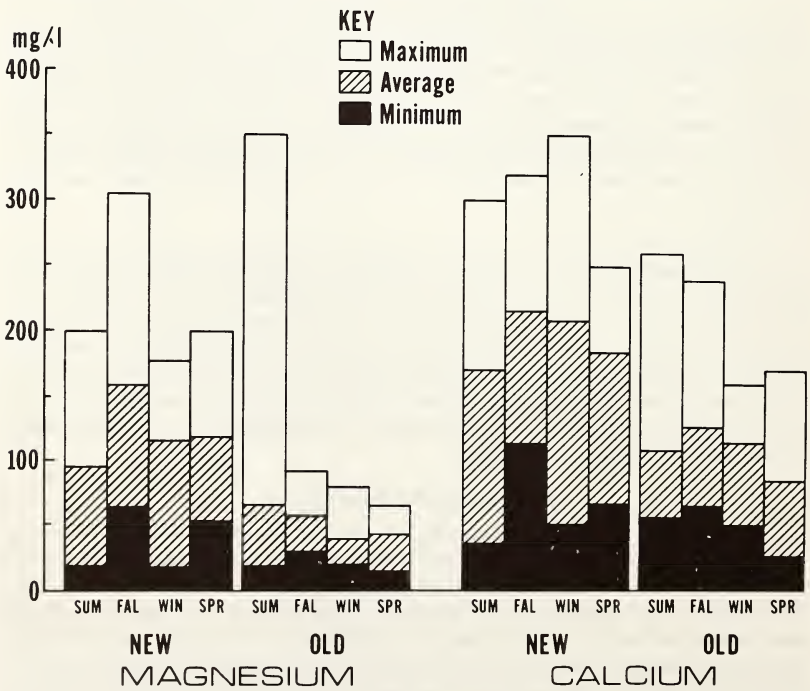

FIGURE 1. *Magnesium and calcium concentrations.*

mines were summer, 109.0; autumn, 127.0; winter, 113.0; and spring, 83.7 mg/l. The calcium ion concentrations were almost always higher in samples taken near new mines because the acidity was neutralized to a greater extent as was shown in the acidity and alkalinity sections.

The maximum chloride ion concentrations near new mines were 49.7, 63.9, 35.5 and 49.7 mg/l for summer, autumn, winter and spring respectively; while the maximum concentrations near derelict mines were 35.5, 63.9, 42.6 and 42.6 mg/l respectively. The minimum concentrations near new mines were 7.1 in summer, 14.1 in autumn, 14.2 in winter and 21.3 mg/l in spring; and the minimum concentrations near derelict mines were 7.1 for summer, 14.2 for autumn, 21.3 for winter and 28.4 mg/l for spring. Average concentrations near new mines were 20.6 in summer, 30.2 in autumn, 25.7 in winter and 32.5 mg/l in spring; while concentrations near derelict mines were 23.1, 40.5, 33.7 and 34.7 mg/l, respectively. For chloride ion concentrations, the results were basically comparable, although the averages tended to be somewhat higher near abandoned mines.

The maximum concentration of dissolved oxygen in streams near new mines was 10.2 in summer, 10.6 in autumn, 9.0 in winter and 7.2 mg/l in spring; while maximum oxygen concentration in streams near derelict mines was 10.6 in summer, 14.8 in autumn, 9.0 in winter and 9.2 mg/l in spring. The minimum concentration near new mines was 5.2 in summer, 5.0 in autumn, 5.8 in winter and 4.0 mg/l in spring; while minimum concentreations near derelict mines were 3.6, 6.2, 4.8 and 3.6 mg/l,

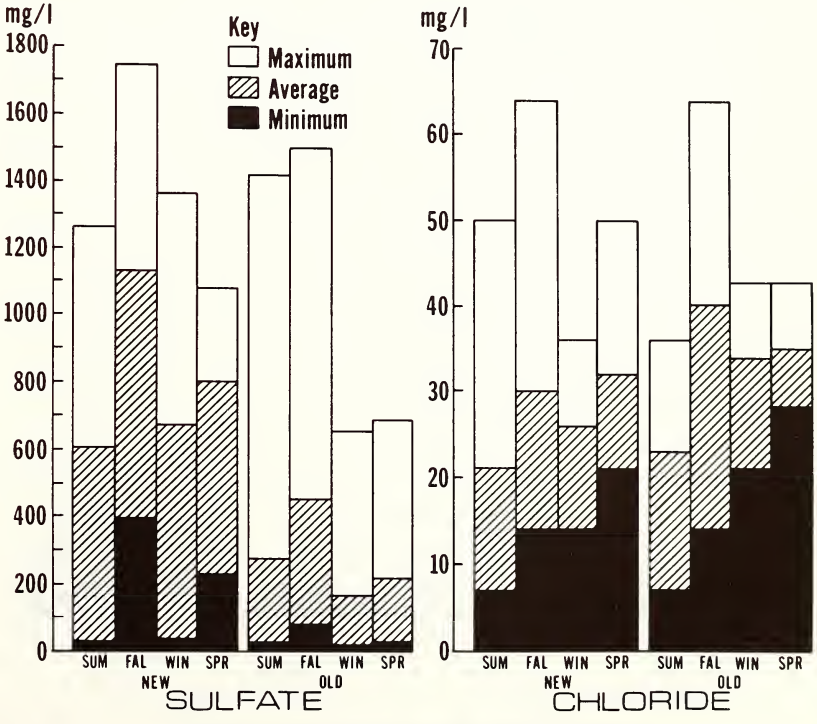

FIGURE 2. *Sulfate and chloride concentrations.*

respectively. The average concentrations near new mines were 7.7, 8.5, 7.4 and 5.8 mg/l; and average concentrations near derelict mines 6.7, 9.1, 6.6 and 5.4 mg/l, respectively, for the seasons under study. The concentrations of dissolved oxygen were relatively high in all measurements, and there was essentially no difference in amounts of oxygen dissolved in streams near new and abandoned mines.

The maximum concentrations of iron near new mines were 4.0 in summer, 9.0 in autumn, 5.0 in winter and 10.0 mg/l in spring; while the maximum concentrations near derelict mines were 43.0 in the summer, 70.0 in autumn, 55.0 in winter and 38.0 mg/l in spring. The minimum concentrations near new mines were 1.0 in summer, 0.5 in autumn, 0.5 in winter and 1.0 mg/l in spring; while the minimum concentrations near derelict mines were 1.0 in summer, 3.0 in autumn, 2.0 in winter and 7.0 mg/l in spring. The average concentrations near new mines were 2.1 in summer, 3.5 in autumn, 2.4 in winter and 3.4 mg/l in spring; while average concentrations near derelict mines were 14.7, 21.6, 20.6 and 14.0 mg/l, respectively, for the seasons under study. The higher concentrations of iron near abandoned mines was probably caused by the greater acidity of the water.

The lead ion maximum concentrations near new mines were 24.0 in summer, 21.0 in autumn, 10.0 in winter and 12.0 in spring. The minimum concentrations were 0.2, 0.1, 0.1 and 0.1 mg/l, respectively, for the seasons under study. The average concentrations near new mines were 8.4 in summer, 8.0 in autumn, 5.5 in winter and 4.2 mg/l in spring. Lead was not detected in samples taken near derelict mines, except in one sample which contained 5.0 mg/l during the summer. Most of

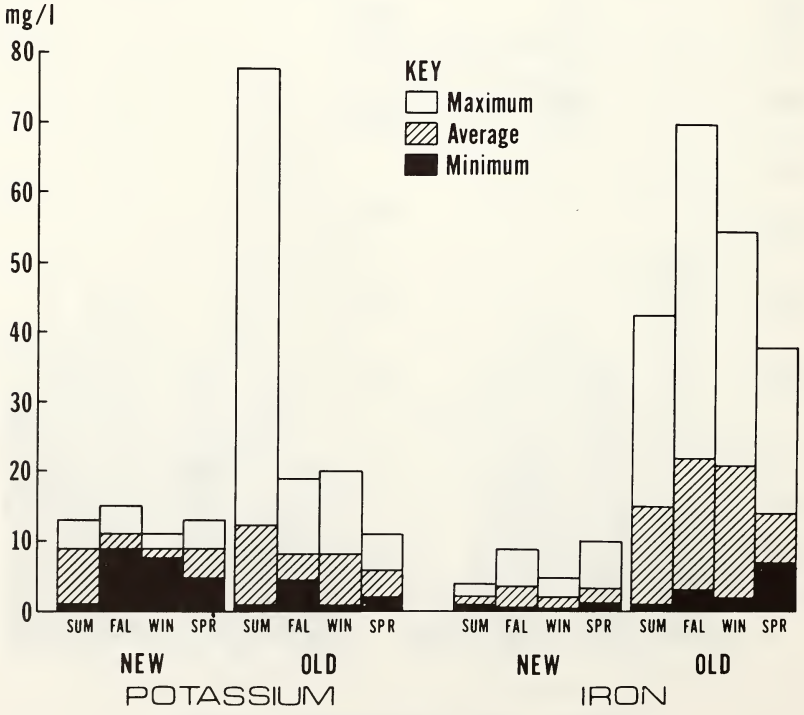

FIGURE 3. *Potassium and iron concentrations.*

the lead had apparently leached out of the areas near abandoned mines after long exposure to the elements.

The maximum concentrations for magnesium ion near new mines were 200.0 in summer, 304.0 in autumn, 175.0 in winter and 200.0 mg/l in spring; while the minimum concentrations were 17.0 in summer, 63.0 in autumn, 16.0 in winter and 52.5 mg/l in spring. The average concentrations near new mines were 96.4 in summer, 158.2 in autumn, 113.6 in winter and 117.8 mg/l in spring. The maximum concentration near derelict mines was 350.0 in summer, 92.0 in autumn, 80.0 in winter and 65.0 mg/l in spring; while the minimum concentrations were 17.0, 30.0, 18.0 and 15.0 mg/l, respectively, for the seasons under study. The average concentrations near derelict mines were 65.4, 56.4, 39.8 and 42.0 mg/l, for the seasons under study. The higher concentrations of magnesium in the samples taken near new mines probably resulted from the greater neutralization of acidity in these streams.

The maximum concentrations for manganese near new mines were 5.0 in summer, 3.0 in autumn, 3.0 in winter and 4.0 mg/l in spring; while the minimum concentrations were 2.5 in summer, 1.0 in autumn, 0.5 in winter and 1.0 mg/l in spring. The average concentrations for the seasons under study were 3.8, 1.8, 2.0 and 1.3 mg/l, respectively. The maximum concentration near derelict mines were 5.0 in summer, 3.0 in autumn, 1.5 in winter and 2.0 mg/l in spring; while the minimum concentrations near derelict mines were 2.3, 1.0, 0.6 and 0.0 mg/l, respectively; and the average concentrations were 3.7 in summer, 1.7 in autumn, 1.0 in winter and 0.0 mg/l in spring. The concentration of manganese was low in all samples. There was a negligible difference in the concentrations of manganese in samples collected near new mines and abandoned mines.

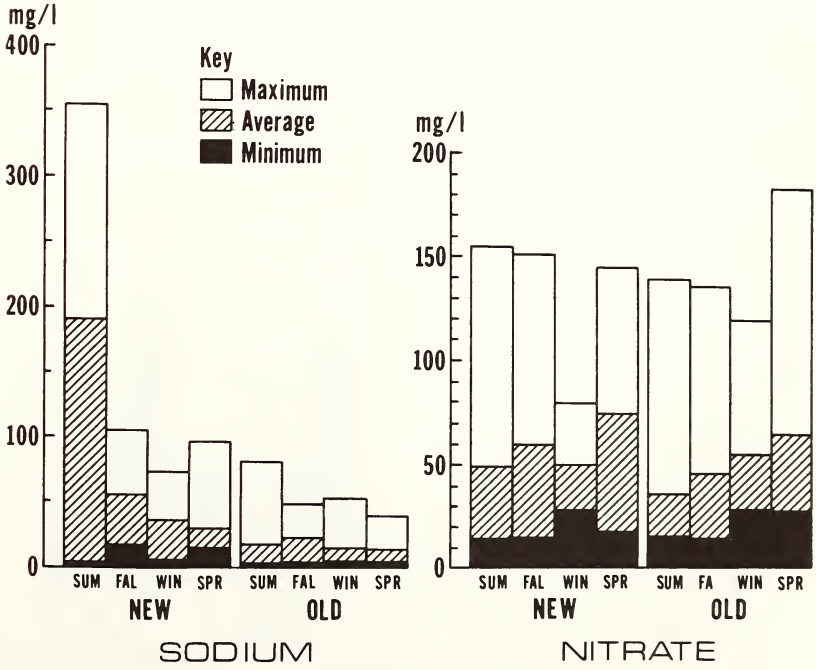

FIGURE 4. *Sodium and nitrate concentrations.*

The nitrate concentrations given in the following discussion are expressed as mg of nitrogen per liter. Maximum concentrations near new mines were 155.0 in summer, 150.6 in autumn, 79.7 in winter and 145.3 mg/l in spring. The minimum concentrations were 14.4 in summer, 14.6 in autumn, 28.4 in winter and 18.4 mg/l in spring. Average concentrations were 48.7 in summer, 59.6 in autumn, 49.8 in winter and 75.1 mg/l in spring. The maximum concentration near derelict mines was 139.1 in summer, 136.4 in autumn, 120.5 in winter and 173.7 mg/l in spring. The minimum concentration was 15.5 in summer, 13.7 in autumn, 28.4 in winter and 26.6 mg/l in spring. Average concentrations were 36.4 in summer, 45.8 in autumn, 55.0 in winter and 65.1 mg/l in spring. The nitrate concentrations were nearly the same near new mines and old mines. In some seasons, the nitrate concentrations were higher near new mines, and in other seasons the nitrate concentrations were higher near old mines.

The maximum pH near new mines was 8.7 in summer, 7.9 in autumn, 7.7 in winter and 7.9 in spring; while the minimum was 7.0 in summer, 6.7 in autumn, 6.7 in winter and 6.3 in spring. The average pH was 7.6 in summer, 7.3 in autumn, 7.3 in winter and 7.4 in spring. The maximums near derelict mines were 8.6, 7.0, 7.0 and 7.3, respectively, for the seasons under study; while the minimums were 6.2 in summer, 6.0 in autumn, 6.1 in winter and 5.8 in spring. The average pH near derelict mines was 7.0 in summer, 6.6 in autumn, 6.6 in winter and 6.6 in spring. The pH generally measured higher near new mines which agrees with the earlier discussion which indicated that acid was further neutralized near new mines than near old mines.

The maximum potassium ion concentrations near new mines were 13.0 in summer, 15.0 in autumn, 11.0 in winter and 13.0 mg/l in spring; while the minimums

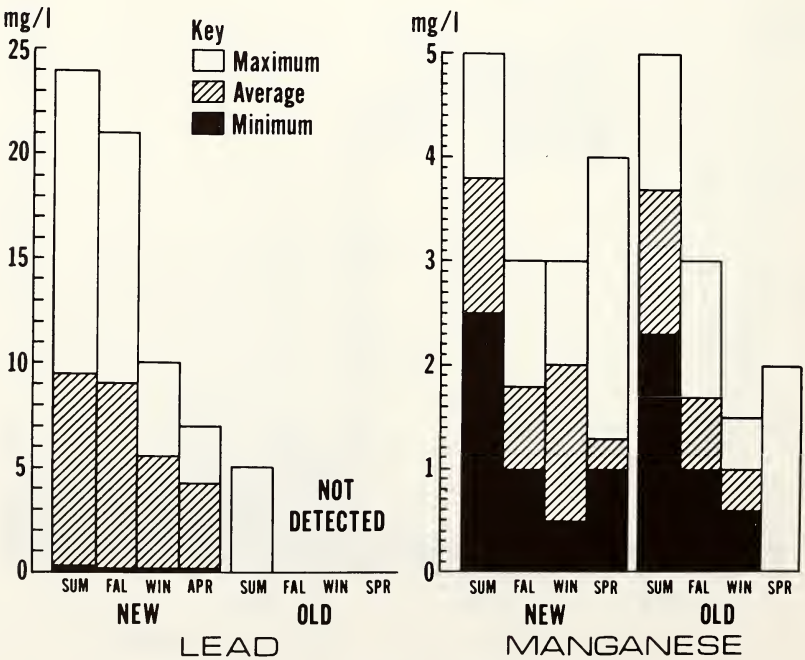

FIGURE 5. *Lead and manganese concentrations.*

were 1.0 in summer, 9.0 in autumn, 7.5 in winter and 5.0 mg/l in spring. The averages were 9.3 in summer, 11.4 in autumn, 9.2 in winter and 8.9 mg/l in spring. The maximums near derelict mines were 78.0 in summer, 19.0 in autumn, 20.0 in winter and 11.0 mg/l in spring; while minimums were 1.0, 4.0, 1.0 and 2.0 mg/l, respectively, for the seasons under study. The average concentration was 11.7 in summer, 8.4 in autumn, 7.5 in winter and 5.6 mg/l in spring. The potassium concentration was sometimes higher near new mines and sometimes higher near old mines. The overall average was about the same near new and old mines.

The maximum sodium ion concentrations near new mines were 352.0 in summer, 103.0 in autumn, 72.0 in winter and 96.0 mg/l in spring; while the minimums were 4.4 in summer, 16.0 in autumn, 7.0 in winter and 15.0 mg/l in spring. The average was 189.8 in summer, 53.7 in autumn, 37.0 in winter and 30.3 mg/l in spring. The maximum concentrations near derelict mines were 81.0 in summer, 48.0 in autumn, 52.0 in winter and 40.0 mg/l in spring; while the minimums were 5.0, 6.0, 7.0 and 6.0 respectively, for the seasons under study. The average was 19.3 in summer, 22.3 in autumn, 15.4 in winter and 13.9 mg/l in spring. The concentration of sodium usually was much higher near new mines. Again, this may have been from the greater extent of neutralization of the acid in the water near the new mines.

The maximum sulfate ion concentrations near new mines were 1260.0 in summer, 1750.0 in autumn, 1370.0 in winter and 1080.0 mg/l in spring; while the minimum concentrations were 36.0 in summer, 390.0 in autumn, 40.0 in winter and 235.0 mg/l in spring. The average concentration was 602.0 in summer, 1135.0 in autumn, 675.5 in winter and 799.2 mg/l in spring. The maximums near derelict mines were 1420.0 in summer, 1500.0 in autumn, 660.0 in winter and 685.0 mg/l in spring; while the minimums were 30.0, 75.0, 20.0 and 25.0 mg/l, respectively, for the seasons under study. The average concentrations were 273.3 in summer, 451.5 in autumn, 168.6 in winter and 214.1 mg/l in spring. The average sulfate concentrations were higher near the new mines, indicating again that more acid was neutralized near the new mines.

The maximum water temperatures near new mines were 27.0 in summer, 19.0 in autumn, 4.0 in winter and 18.0°C in spring. The minimums were 17.0 in summer, 1.0 in autumn, 0.0 in winter and 7.0°C in spring; while the averages were 23.6, 11.1, 1.8 and 12.9°C, respectively, for the seasons under study. The maximum water temperatures near derelict mines were 27.0 in summer, 18.5 in autumn, 6.0 in winter and 18.0°C in spring; while the minimums were 16.0 in summer, 2.0 in autumn, 0.0 in winter and 7.0 in spring. Average temperatures near derelict mines were 22.1 in summer, 10.7 in autumn, 2.7 in winter and 12.7°C in spring. There was no detectable differences in the temperatures of the water in the streams near new and old mines.

The maximum turbidity in the water near new mines was 112.0 in summer, 53.0 in autumn, 58.0 in winter and 85.0 in spring; while the minimums were 1.0 in summer, 2.0 in autumn, 3.0 in winter and 4.0 in spring. The average was 23.8 in summer, 11.2 in autumn, 27.2 in winter and 15.6 in spring. The maximums near derelict mines were 300.0 in summer, 345.0 in autumn, 345.0 in winter and 300.0 in spring. The minimums were 37.0 in summer, 55.0 in autumn, 43.0 in winter and 37.0 in spring; while the averages were 163.0 in summer, 164.1 in autumn, 128.9 in winter and 128.5 in spring. A great quantity of rusty-red iron-containing particles were present in the water near abandoned mines, explaining the high turbidity in the water in the streams near old mines.

Acknowledgment

The authors wish to thank the Indiana State University Research Committee for a grant for partial support of this research.

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GEOLOGY AND GEOGRAPHY

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ABSTRACTS

Pennsylvanian Oil and Gas Occurrences in Sullivan County, Indiana. SCOT ADAMS, DAMES and MOORE, Cincinnati, Ohio 45203 and GUNNAR KULLERUD, Department of Geosciences, Purdue University, West Lafayette, Indiana 47907.——Data obtained from geophysical logs and petroleum, coal, and water well drillers' logs were examined to determine which Pennsylvanian stratigraphic horizons or intervals are associated with oil and gas.

Most electric logs gave no significant indications of petroleum content. Some gas zones were represented strongly in association with conductive formation fluids over Silurian reef structures. Long lateral resistivity logs defined gas zones well under these conditions. Resistivity logs with a 64 inch spacing demonstrated some response in these zones. Because of infiltration of drilling fluids, 16 inch logs failed to detect gas zones well.

Above the horizon of the Seelyville Coal, 384 records indicated a strong affiliation of oil and gas occurrences with coal seams coupled with black shales. This type of association is more common than are associations of the thicker clastic sediment intervals with oil and gas. Clastic units between the Houchin Creek and Survant horizons and between the Colchester and Seelyville horizons demonstrated a higher rate of occurrence of oil and gas than other clastic units above the Seelyville Coal. This is attributed to the larger maximum grain size and better sorting of sands in these particular intervals.

No mappable horizons were detected within the Pennsylvanian sediments below the Seelyville Coal seam. Therefore these sediments were referenced with respect to their distances below the Seelyville Coal. One hundred and ninety of these petroleum occurrences were plotted on a frequency histogram with 10 foot class intervals. No significant zones of increased petroleum accumulation were indicated. Beneath the Seelyville coal petroleum fluids were frequently found in sand horizons adjacent to black shales.

Some gas occurrences, as thick as 20 feet, were indicated on electric resistivity logs within areas of maximum Pennsylvanian structural closure over Silurian reefs. Drillers' logs indicate multiple horizon occurrences of gas and oil over these structures. Pennsylvanian structures, resulting from the influence of Mississippian unconformity bedrock highs, did not appear to exert an influence upon the location of oil and gas occurrences. Accumulations were as common over Mississippian unconformity valleys as over unconformity ridges.

Past production intervals are thin and discontinuous. Permeability appears to be limited by overall clay richness of the sediments, owing to a fluvialy dominated delta depositional influence. The distribution of occurrences appears to be somewhat random. Future prospects for significant Pennsylvanian oil and gas production are adverse. Some potential exists for domestic or farm gas supplies. Six occurrences of gas in Pleistocene sediments were noted.

Computer Generated Stereograms. ROBERT F. BLAKELY, Indiana Geological Survey, Bloomington, Indiana 47405.——Points located in space by X,Y,Z coordinates can be plotted in two dimensions using the relations $X_p = X\sin(A) + y\cos(A)$ and $Y_p = Z\cos(B) - (X\cos(A) + Y\sin(A))\sin(B)$. A is the angle between the X axis and the line of sight and B is the angle between the X-Y plane and that line. Using these expressions, points may be plotted or connected to draw three dimensional objects as viewed from any direction. By viewing the same subject from two slightly different directions, stereo pairs may be plotted. Hidden lines in stereograms are beneficial in rendering the object transparent and transmitting information about the image.

Correlation and Nomenclature of Middle Ordovician Stratigraphic Units in Indiana. JOHN B. DROSTE and TALAL F. ABDULKAREEM, Indiana University, Bloomington, Indiana 47405 and JOHN B. PATTON, Indiana University and Indiana Geological Survey, Bloomington, Indiana 47405.——Stratigraphic units of the Champlainian Series defined through surface exposures ranging from the flanks of the Ozark Mountains to the upper Mississippi Valley have traceable physical continuity into the subsurface in Indiana, where they are bounded below by the Knox Dolomite and above by the Trenton Limestone and its equivalents.

The Everton Dolomite, bounded above and below by significant unconformities, and the oldest unit of this series, is recognized only in the subsurface of southwesternmost Indiana. The Ancell Group, superjacent to the Everton Dolomite and of Chazyan and early Blackriverian age, consists of the St. Peter Sandstone and two formations with which it is in facies relationship, the Dutchtown Formation below and the Joachim Dolomite above. All or parts of the Ancell Group are found throughout the subsurface of Indiana. The Dutchtown correlates with rocks called Wells Creek in Ohio and Kentucky, and the Joachim correlates with three informally named members in the lower part of the Black River Limestone of southwestern Ohio.

The Black River Group of Indiana consists of two formations, the Pecatonica Formation below and the Plattin Formation above, that are recognized throughout the subsurface of Indiana. The Pecatonica is traceable into western Kentucky (where the same name is used), but it is uncertain that it continues very far east of the Indiana-Ohio boundary.

The Kolarik Mastodon Site. GARY D. ELLIS, Indiana Division of Historic Preservation and Archaeology, Indianapolis, Indiana 46204.——In August of 1980 the Indiana State Museum excavated, under the direction of the author, a late Pleistocene Mastodon (Mammut americanum) death site near Ora, Starke County, Indiana. In addition to the Mastodon remains, a nearly complete Caribou (Rangifer sp.) antler was recovered from associated context. The excellent state of floral and faunal preservation and the undisturbed site contexts provide an encapsulation of early post-Wisconsin life in northern Indiana. Unique on-site and laboratory bone conservation measures and the application of an innovative freeze-dry bone preservation procedure for the mega-faunal assemblage permitted an efficient and cost effective data recovery program.

Current Applications of Interactive Geographic Data Bases and Land Data Systems. GLENN MONTGOMERY, Mid-States Engineering Company, Inc., Indianapolis, Indiana.——A major problem concerning most natural resource and land planning problems involves the comprehensive and often complex task of compiling, accessing and managing information. Frequently, massive and seemingly

unrelated data must be analyzed to spot problems and highlight possible planning solutions. Within the last two years major technological advances in the field of interactive computer graphics are providing resource planners with advance tools for the storage, retrieval, manipulation and re-combination of planning data from virtually any source document. Meshing emerging interactive graphics with the concept of a geographic database and linked graphic (map) and non-graphic (record) files, planners and resource managers are now realizing new levels of analytical flexibility and research productivity.

Mid-States Engineering, an Indianapolis based consulting engineering firm, specializing in land planning, photogrammetric engineering and related services, recently installed the first of a new generation of interactive computer graphics systems. Utilizing the unusual capabilities of this system, this paper briefly reviews conceptual planning, design, organization and construction of digital graphic databases; digitization from existing maps or photogrammetric compilation, and the creation of new maps from coordinate geometric data. Several local environmental inventory and analysis applications will be reviewed.

Identification of the Twocreekan Substage in Indiana. ALLAN F. SCHNEIDER, University of Wisconsin-Parkside, Kenosha, Wisconsin 53141, and MARK RESHKIN, Indiana University-Northwest, Gary, Indiana 46408.——The Twocreekan Substage of the Wisconsinan Stage of glaciation is generally regarded as an important time-stratigraphic unit in the late Quaternary glacial chronology of the Midwest. Botanical (palynological) evidence for the Twocreekan interstade in Indiana was recognized many years ago in pollen diagrams by Frey (northern Indiana) and Engelhardt (central Indiana). Geological (stratigraphic) evidence for its identification has not been previously reported, however, partly because ice deposits of immediate pre-Twocreekan (late Woodfordian or Port Huron) age and immediate post-Twocreekan (Valderan or Greatlakean) age are not present in Indiana, as they are farther north. Furthermore, recognition of the Twocreekan interval has not been indicated by radiometric dates.

A previously unreported ^{14}C date of 11,815 ± 640 yrs. B.P. (IU-67) on wood from a thin organic horizon near the base of a 6-meter section of lacustrine sediments in northern Lake County thus represents the first positive geologic identification of the Twocreekan Substage in Indiana. The identification is strengthened by two post-Twocreekan radiocarbon dates, also not previously reported, of 10,890 ± 560 yrs. (IU-69) and 9,100 ± 640 yrs (IU-68) on wood specimens from organic horizons higher in the stratigraphic section at the same locality. The Twocreekan assignment is further supported by the fact that the dated layer overlies calcareous clayey till that is either Tinley or Lake Border till and thus can be no younger than the Glenwood II state of glacial Lake Chicago, which has been dated previously from independent evidence as about 12,000 to 12,600 radiocarbon years B.P.

A Study of Lake Chicago Calumet Beach Sediments. ALFRED T. SMITH and PERRY E. ZACK, Indiana University Northwest, Gary, Indiana 46408.——Three consecutive and distinct environments contributed to the formation of the Calumet Beach of glacial Lake Chicago in the Gary quadrangle of Indiana. A low lake-level period that occurred between two equally high lake-levels resulted in the deposition of a peat layer between two similar arrays of lacustrine beach sediments. This sequence of deposits provides a distinction between the Calumet lake stages in the lakeshore region.

Construction of an Apartment/Social Center Complex in Karst Terrain, Bloomington, Indiana. TERRY R. WEST, Department of Geosciences, Purdue University, West Lafayette, Indiana 47907 and THOMAS KALLIO and DAVID WARDER, ATEC Associates, Inc.——Karstic terrain such as that found in Bloomington, Indiana requires careful consideration during design and construction. Disruption of subsurface drainage patterns and/or excessive loading of cavernous bedrock must be avoided, or significant damage to construction can occur.

To assess the construction feasibility of a three story apartment/social center complex on the north side of Bloomington, shallow surface-depressions were mapped and lithologic trends evaluated. Solutioning along primary and secondary joints in the thick-bedded, dense, biofragmented Harrodsburg Limestone and the overlying, several few feet of lower Salem Limestone (both Mississippian Age) was believed responsible for karstic conditions at the site. The vertical extent of these features was predicted to be limited to a zone above a sequence of interbedded shale (Elevation 760). Further, surface expression of sinkholes was thought to have developed from collapsed soil plugs settling into enlarged vertical pipes formed at the junction of joint sets.

Although sinkhole development is a slow, geologic process, which would not be expected to occur during the life of the structure, the potential for loss of foundation support from these pipes poses a construction threat. Actual conditions revealed by inspection of sinkholes during construction were generally consistent with the original interpretative study. Solutioning was found to be more strongly developed along primary joints, these trending slightly closer, (between N65° to 80°E) to the regional pattern (N81°E) than originally anticipated. Enlarged vertical openings were found at the junction of joint sets in several locations. However, local variations in lithologic composition, and to a lesser extent, solutioning along bedding planes, were also contributing factors warranting future interpretation.

The proposed method for treating karstic conditions within the limits of load bearing foundations of the main building and for other related structures, focused on maintaining subsurface drainage, structural support and soil moisture equilibrium. To accomplish this end, the soil was cleaned from each sinkhole on both the sides and bottom prior to backfilling with a layer several feet thick of large sized crushed stone. A reinforced concrete pad, with vertical drains was placed over the filled sinkhole and supported on the rock bench above the active solution pit. Crushed stone overlain by filter fabric was placed over the concrete pad to serve as a drainage filter. Finally, natural clay fill from the site was placed and compacted over the depressions as needed to establish the foundation grade.

Designing Residential Islands

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The Enmeshing Web

As early as the middle of the 20th century in most United States cities of over 100,000 inhabitants, circulation-business-industrial (CBI) corridors had sliced through and surrounded former extensive continuous residential areas forming a web pattern. The web pattern concept of city growth has been presented in earlier papers. (1) The most recent of these on the web pattern of circulation-business-industrial (CBI) corridors and the residential islands, the corridors encompass is "Conserving Energy and Natural Resources with a Web Pattern of Corridors" read at the International meeting of the Advanced Transit Association on April 26, 1978. (2) Briefly, the web pattern of city physical development materialized as strip businesses which coalesced and joined multiple nuclei centers with each other and the downtowns. This process forms huge web-shaped corridors of circulation-business-industry (CBI) throughout large cities. In Chicago the web is referred to as corridors of high accessibility. The process continues with the web of corridors becoming thicker and more extensive to the detriment of the adjacent and enmeshed neighborhoods. Apparently, the city officials who permitted the CBI corridors to develop by granting innumerable variances in land originally zoned for residential purposes and others who later zoned the corridor development, gave little consideration to the influence that these corridors would have on residential land. City officials and city planning departments also worked with state highway departments to design, locate and build interstate highways and limited access freeways through and around residential areas. The records of numerous residential zoning variances indicate that both government agencies and the petitioners strongly supported the philosophy that transportation, business and industrial uses should have a higher priority than residential. It is only within the last decade or two that people began to challenge the right of street and highway management to slice through and subdivide residential areas.

The Problem

Regardless of how CBI corridors were built, these hugh city-wide encompassing webs do exist and so do the residential islands or cells they enclose. Within these residential cells live millions of people in detached dwellings valued in the billions and in which billions of dollars have been invested in both public and private infrastructure service systems. Residential life and these investments are under constant threat of disruption and/or deterioration which so often results in slums.

Whether a city grows in population or not, the use of its land is not static. In the past, residential users of land primarily played a passive role, and those who wished to convert residential land to other uses have been aggressive. In some cases the promoters have cut away parcels of land from neighborhoods and communities until corridors have penetrated through creating additional residential cells by subdivision. In other cases residential communities have been overwhelmed by huge encompassing developmental projects, such as the interstate highway routes cutting through and surrounding Indianapolis.

The processes which produce the web pattern of corridors and residential islands or cells are continuous. Each year and each decade extending corridors cut through and close around neightborhoods and communities dividing and redividing many former thriving residential areas and the process of physical deterioration and economic and social decline accelerates. Too often people are partially stranded on one side of the corridors and their social institutions of churches, lodges and schools on the other.

A Residential Cell Model

To remain stable, prosperous and desirable, neighborhoods and communities need to 1. be relatively large, 2. hold through traffic to a minimum and 3. be as pollution-free as possible, which includes preventing the spread of individual residence deterioration.

Size. It is imperative to keep residential areas large enough to adequately provide four or five neighborhoods, and a community with at least a minimum of the desirable services such as detached houses, duplexes and apartments as well as elementary schools, a community high school, playgrounds and neighborhood and community shopping centers with convenience goods (Figure 1). Since relatively low cost, yet efficient, city services whether education or garbage collection is related to size of population, in order to keep the per capita costs to a minimum it would be desirable that neighborhoods have populations from 15 to 20 thousand, and a community 60 to 80 thousand. Neighborhoods may cover an area of 320 to 640 acres.

Enmeshed small residential areas of eighty acres or less often develop serious problems. If a smaller residential area has been sliced from a larger one and is found sandwiched between a larger area and an arterial street and a railroad, it may be possible to change this small residential area to light-weight industrial and a community shopping center as indicated in Figure 1.

Or, if the smaller residential meshes are not too numerous and are adjacent to the downtowns, some of them may be converted to multiple-dwelling units for childless dwellers. In former years when business downtowns were expanding horizontally rather rapidly one could assume that in the near future these small residential cells would be converted to business use. But today, because of the shift to huge shopping centers and industrial parks on the periphery of large cities and suburban residential expansion, it could be possible that small residential cells be used for center city recreation such as museums and sports arenas and parks which would serve a city's entire population, not just a community.

Through traffic. Through traffic is an abomination to an otherwise quiet residential area. It adds to and is often a major contributor to high traffic density, accidents and congestion on narrow streets. Such traffic is often dirty and too often is the major factor in producing unsightly streets, with broken curbs, trash-clogged drainage outlets, litter and damaged shrubs and shade trees. Through traffic vehicles often carry heavier loads than the residential streets were built to bear causing rapid deterioration resulting in broken pavements, chugholes and patched repairs. Through traffic drivers and their vehicles handicap normal residential activities. Persons backing their cars from driveways, bicycle riders, local transit buses with their frequent stops, pedestrians and other activities causing slow traffic flow, are an irritation.

Two of the primary ways to greatly reduce if not eliminate through traffic are 1. not to provide or, if possible, reduce and eliminate straight streets crossing a

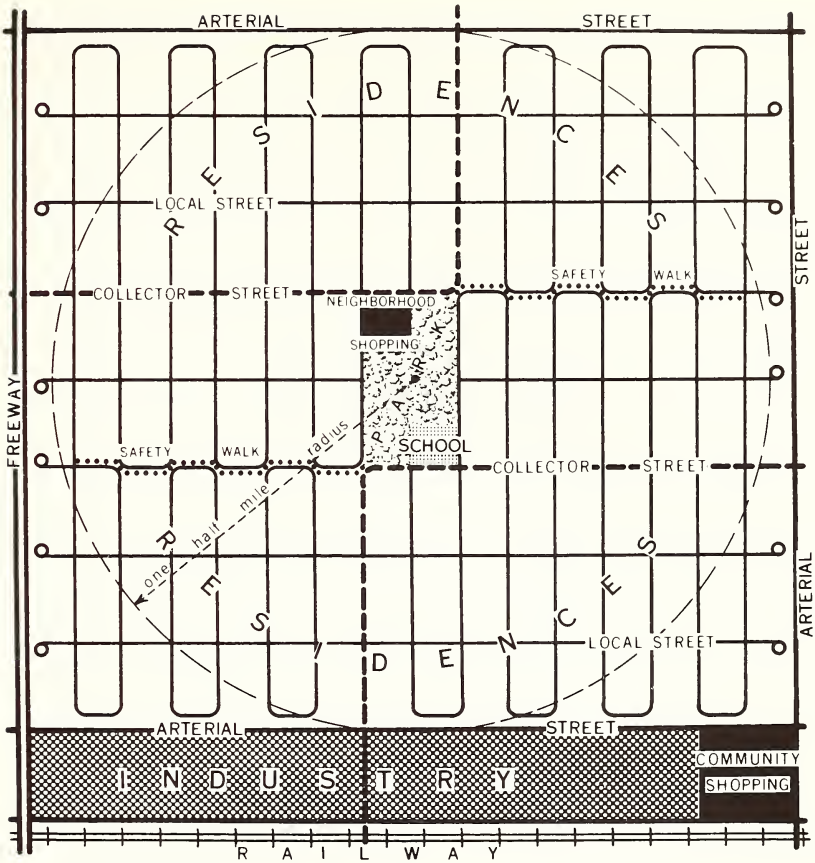

FIGURE 1. *Model of a Resential Island*

neighborhood and 2. build numerous dead-end streets with only cul-de-sac and hairpin turns.

The residential model in Figure 1 shows four access entrances to and from the major arterials and freeway which bound the approximately square mile area. Notice that the two L-shaped collector streets provide easy access to and from the residential cell and the rest of the city without being joined together and without crossing two major safety walks that provide residents with access to the park, school and shopping center. Moreover, there are no straight mile-long local streets connecting the residential cell to the arterials. The local streets are designed to slow the speed of traffic and discourage non-residents, except visitors and small commercial vehicles serving the local residents. The dead-end streets with only cul-de-sac and hairpin turns present a problem to through traffic drivers who would quickly learn to avoid the area.

Then with through traffic partially eliminated from the neighborhood, several steps could be taken to lower construction and maintenance costs. None of the streets here need to be as wide or the pavement as thick as is that of arterials and

the freeway which borders the neighborhood. Both the weight and size of the vehicles entering this cell should be limited. With notices posted at the overhead gate entrances that have a clearance height adequate only for cars, small service trucks and small transit buses if necessary. School buses need not enter the area since all of the elementary children would be living about half a mile or less from the neighborhood school and could walk that distance. Park, shopping center and health clinic, and day care center, if these were added to the center neighborhood complex, would also be within walking distance. High school students could walk or bicycle to the collector street entrances.

With through traffic pratically eliminated and a strong neighborhood association in operation, non-motor bicycle lanes could be marked so that bicycling would be relatively safe for anyone to ride anywhere in the neighborhood, and to the four collector street exits and entrances. On the exit side, parking areas could be made available for those wishing to park bicycles and cars and take mass transit at the stops located just outside. By eliminating the big buses and trucks from the local streets and safeguarding pedestrians and motorless bicycle riders, walking and bicycling would be encouraged, thus improving the health of the neighborhood, and gasoline conservation would be supported.

Pollution. Residential islands are subjected to pollution originating 1. within a neighborhood and community, 2. in the CBI corridors which surround these residential areas, 3. from other parts of their metropolitan area and 4. in places miles from the home city.

It only takes a few residential yards cluttered with 1. corroded and broken-down water- and eve-spouts (the latter filled with leaves and young sprouting plants, 2. broken and discarded T.V. aerials, 3. broken windows, screens, porches, steps and sidewalks, 4. peeling house paint, 5. fences in disarray, 6. ill-smelling garbage cans and litter at pick-up sites, 7. various types of litter such as paper and boxes, discarded food and wrappings, bottles and cans, and 8. junk bicycles and cars infested with rats, to start the decline of a neighborhood. Unless peer pressure and/or group help in maintenance, operating individually or through strong active groups, can control such types of refuse and reduce or eliminate intra-neighborhood pollution sources, it is not realistic to believe that the residents can have much influence on the control of pollution coming into its area.

Neighborhood pollution originating in the adjacent CBI corridors is more difficult to reduce. Typically these corridors abound in sound, smell, sight and air pollution. 1. The increasing noisy traffic, 2. unsightly litter and smelly garbage, 3. the ill-smelling gasoline exhaust and other fumes, 4. the dirt laden air and dust, 5. the noises associated with loading and unloading, 6. the sirens and flashing lights of police, fire and ambulance vehicles, 7. the flashing ugly neon signs and billboards and 8. other numerous activities which help produce sound, sight, smell and air pollution are all a part of CBI corridors activity that flows and swirls around the enmeshed residential cells.

Neighborhood associations have two primary approaches to reduce CBI corridor pollution. One is to shield their neighborhood and the other is to bring pressures on city agencies to better control and help reduce excessive corridor pollution. Both approaches involve long-ranged planning. In the model of a residential island presented in this paper, the two primary sources of pollution will be from 1. the freeway on the left and 2. the arterial street serving both the neighborhood and industries and the community shopping center complex at the bottom. One of the two most frequently advocated and used methods of screening is the planting of

trees and shrubs to form a thick greenway. Another would be to zone strips of land designated as a parkway in which a limited number of future houses and condominiums, three to six stories high, may be built parallel to the freeway.

If a neighborhood holds intra-neighborhood pollution to a minimum and does all it is physically possible to shield pollution from coming in from other areas, it will be in a strong strategic position to bring pressure on city officials to reduce pollution in the adjacent CBI corridors, the metropolitan area and pollution originating in more distant areas.

Guidelines and Pilot Projects

According to the 621-page report of the National Commission on Neighborhoods, released in 1979, federal, state and local governments do not even have a workable generally accepted definition of what a neighborhood is. (3) The neighborhoods treated in this paper are physical neighborhoods because they have come into being by being surrounded by CBI corridors. The people living in the cells may be a mixture of different ethnic, minority and/or economic groups. The people in the residential cells will need to cooperate and work together to maintain, upgrade and protect the neighborhood from physical encroachment and internal deline. A discussion of guidelines and a potential protective planning model for a neighborhood are only academic unless a great majority of the people will participate in dynamic neighborhod and community organizations.

There are now neighborhood redevelopment pilot projects in the United States. In Baltimore, the Coldspring neighborhood with approximately 12,800 people living in 3,780 dwelling units on 370 acres is being redeveloped as a pedestrian oriented district with only one road crossing the area. (4) When the redevelopment is completed children will be able to walk to school and neighborhood markets. Workers will be employed within walking distance of their homes.

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A Social Impact Assessment of the Brookville Reservoir

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Introduction

The Institute of Environmental Sciences (IES), Miami University, Oxford, Ohio, and the Whitewater Valley Jaycees, Union County, Indiana, cooperated on an investigation to evaluate the impact of the Brookville Reservoir on the residents of this area.

The Study Site—The Brookville Reservoir is located in Franklin and Union Counties in southeastern Indiana. A map of the study area has been previously presented (4). Authorized by the Flood Control Act of 1938, the Reservoir is to provide flood protection in the lower Whitewater and Miami River Valleys and to reduce flood stages at all points down the Ohio River Valley. Other purposes of the Reservoir are to provide a lake for general recreation, fishing, wildlife activities, and water supply storage for the state of Indiana. Construction of the dam began in November, 1965, and impoundment of the lake began in January, 1974 (7). Most lake and recreational facilities were formally open to the public in the summer of 1975.

Union County, Indiana, is a small, rural county with a population of 6582 persons in 1970. Liberty is the major population center with a population in 1970 of 1831 persons (8). Of Indiana's 92 counties, Union ranked 90th in total population in 1970 (2). Of the four Indiana counties (Fayette, Franklin, Union, and Wayne) which comprise the Brookville Reservoir area, Union has the highest percentage of its land (88.1%) devoted to agriculture (7).

Other studies have indicated that large federal projects, such as the Brookville Reservoir, have various impacts on the neighboring geographical areas (1,5). The social impact of such a project tends to be more severe in rural areas due to the stable nature of the rural social system. It is expected that Union County will experience the greatest environmental, social, and economic impact among the counties in the Reservoir area because of its rural-based economy, its small population, and the fact that three of its six townships contain the Reservoir.

Methodology

This investigation was composed of three parts. First, traffic counts were conducted on three major routes within the county. Second, activities and needs of visitors to the Brookville Reservoir were assessed by means of a questionnaire. Third, a random survey of Union County residents was conducted to assess their concerns regarding the growth of the county. The investigation was conducted from 1 July to 31 December 1976.

Traffic Counts—Traffic was monitored on westbound US 27 at it intersection with Indiana SR 101 and both north- and southbound Indiana SR 101 at the southern boundary of the town of Liberty six times during the summer of 1976 to estimate the effect of the Brookville Reservoir on the traffic volume in Union County. No traffic counts had been conducted since the Reservoir was opened to the public. Traffic was monitored for a 24-hour period beginning at 1700 h on each of the following dates: 2, 16, and 26 July, 6 and 16 August, and 3 September. These dates were chosen to provide data on two typical holidays (2 July and 3 September),

two typical weekends (16 July and 6 August), and two typical weekdays (26 July and 16 August). US 27 and SR 101 were chosen because they would most likely be impacted by the Reservoir facility.

Totals were tabulated on an hourly basis. Vehicles were classified into the following categories: automobiles, light trucks, trucks, tractor/trailer trucks, motorcycles, and buses. Totals were also kept for motor homes, pickup campers, boat trailers, travel trailers, and campers. Finally, the states in which the vehicles were licensed were noted for each vehicle. Thus, it could be determined what percentage of the county's traffic was from out-of-state.

Visitor Survey—A five-page questionnaire was prepared for distribution at the Reservoir in an effort to asses visitors' activities and needs. The questionnaire was distributed on the day following each of the traffic counts (i.e., 4 July, 18 July, 28 July, 8 August, 18 August, and 5 September). Since the Brookville Reservoir has a total of nine entrances, it was decided that the questionnaire would be distributed after the visitors had entered the park. The six areas where the questionnaire was distributed were the beach area, the picnic area at the Mounds Recreation Site, the campgrounds, Quakertown Boat Ramp, the Treaty Line Museum, and the Bonwell Boat Ramp. Since the campgrounds had numbered lots, every third lot was selected for questionnaire distribution. Every effort was made to randomly select persons at each site. This method fulfilled that requirement of randomness which states that each individual should have an equal chance of selection (6). Location was considered to be a random phenomena for each individual.

The visitor questionnaire was divided into five parts. Part I was concerned with the socio-economic characteristics of the visitor group. Part II sought to establish how far the individual traveled, which routes were taken, and what vehicles were brought. Part III dealt with visitor activity at the Reservoir. Part IV sought to determine the economic activities of the visitors in the Reservoir area. Part V sought to establish what facilities the visitors would use if those facilities were present and how far the visitors would travel to make use of such facilities.

Resident Survey—A survey of the residents of Union County was conducted in an attempt to obtain a representative sample of opinions concerning growth of the county. On 29 November 1976, 800 questionnaires were mailed to randomly selected households in Union County. Participants were randomly selected from telephone directories which serve the county.

Questions 1 through 6 on the questionnaire dealt with some general characteristics of the household. Questions 7 and 8 asked the respondents to state the annnual increase in population and housing that they felt to be the most desirable for Union County. Questions 9 and 10 asked the respondents how they felt housing and commercial development should take place. Question 11 asked the respondents to state the degree of desirability that they associated with various areas of change that would likely occur were Union County to experience growth.

Results and Discussion

Traffic Counts—Traffic data are summarized in Table 1. These data were compared to previous traffic counts conducted by the Indiana State Highway Commission in 1948, 1962, and 1969 (3).

There are two major points of interest concerning these comparisons. First, the 1976 totals increased from an average of 1995 vehicles for weekdays to an average of 2743 vehicles for weekends to an average of 3066 vehicles for holiday weekends. This increase is expected on a route that carries recreationally-oriented

TABLE 1. *Summary of 24-hour totals for all vehicles*

Date	US 27 West	SR 101 North	SR 101 South
26-27 July (weekday)	2036	2101	2005
16-17 August (weekday)	2007	1872	1950
16-17 July (weekend)	2767	2662	3623
6-7 August (weekend)	2380	2184	2843
2-3 July (holiday weekend)	3492	2658	3701
3-4 September (holiday weekend)	2636	2476	3434

traffic and suggests that the Brookville Reservoir has already manifested an impact on traffic volume.

The second point of interest is the large increase in traffic between the years 1969 and 1976. In 1948, the 24-hour annual average of total traffic on SR 101 was 1100 vehicles; in 1962, it was 1725 vehicles; and in 1969, it was 2150 vehicles. Whereas the annual percentage of increase for the seven years between 1962 and 1969 was only 3.25% per year, the annual percentge of increase for the seven years between 1969 and 1976 was 12.05% per year. The three fold annual percentage increase strongly suggests that the Reservoir had a significant impact on Union County traffic volumes even prior to its official opening in 1975. This threefold increase was obtained when using only the 1976 average number of vehicles on a weekday. It is, therefore, a conservative figure.

The average 24-hour weekday total, the average weekend total, and the average holiday weekend totals for westbound traffic on US 27 in 1976 were 2021, 2573, and 3063 vehicles, respectively. Interestingly, the average weekday total for westbound traffic in 1976 represented 73% of the total traffic (east and westbound) found in 1969. Like SR 101, traffic totals increased from a low for weekdays to a high for holiday weekends, again suggesting recreationally-oriented traffic.

Since separate totals were kept for pickup campers, boat trailers, travel trailers, motor homes, and campers, it was possible to discover what percentage of the traffic was recreationally-oriented. It was determined that 3.6% the weekday, 5.8% of the weekend, and 7.7% of the holiday weekend traffic volume was composed of recreationally-oriented vehicles. These data demonstrate that increases in volumes on normal weekends and holiday weekends are, in part, a result of increases in recreationally-oriented traffic, indicating again that the Brookville Reservoir has had an impact on Union County traffic volumes.

It is difficult to determine the exact impact of the Brookville Reservoir on traffic volume in Union County since the origin and destination of each vehicle is unknown. However, an estimate can be calculated using park data which show that, in 1976, 1,202,212 persons representing 389,508 vehicles visited the Brookville Reservoir (personal communication, Michael Graham, Head Ranger, U. S. Army Corps of Engineers, Louisville Office). Results from the visitor survey show that 33.8% of the visitors who were surveyed traveled through Union County. This provides an estimate of 131, 654 vehicles in the county due directly to the Reservoir. This estimate of 131,654 vehicles, however, includes only those vehicles that entered the Reservoir. Vehicles not considered include those coming to or going from the various campgrounds in close proximity to the Reservoir, vehicles carry-

ing commercial goods to commercial establishments that were attracted to the area due to the Reservoir, and vehicles carrying people searching for seasonal or permanent residences near the Reservoir.

TABLE 2. *Percentage of vehicular composition by state.*

Date	Route	Ohio (%)	Indiana (%)	Other (%)	Total Out-of-State (%)
26-27 July	US 27	18.0	72.2	9.8	27.8
(weekday)	IND 101	9.3	88.8	1.9	11.2
16-17 August	US 27	19.0	74.4	6.6	25.6
(weekday)	IND 101	11.5	85.9	2.6	14.1
16-17 July	US 27	25.4	69.0	5.6	31.0
(weekend)	IND 101	19.2	77.8	3.0	22.2
6-7 August	US 27	26.3	68.3	5.4	31.7
(weekend)	IND 101	15.3	83.2	1.5	16.8
2-3 July	US 27	23.8	67.4	8.8	32.6
(holiday weekend)	IND 101	19.4	76.3	4.3	23.7
3-4 September	US 27	26.5	64.5	9.0	35.5
(holiday weekend)	IND 101	22.1	76.8	1.1	23.2

Table 2 lists the percentage of vehicles registered in Ohio, Indiana, and all other states that were traveling on US 27 and SR 101 on the given dates. The percentage of out-of-state traffic on SR 101 increased from an average low of 12.6% on weekdays to an average high of 23.4% on holiday weekends. The percentage of out-of-state traffic on westbound US 27 increased from an average low of 26.7% on weekdays to an average high of 34.0% on holiday weekends. The total percentage of out-of-state recreationally-oriented vehicles traveling SR 101 and US 27 westbound increased from 38.6% on weekdays to 47.8% on holiday weekends. The typical weekend percentage was 46.1%. Vehicles from Ohio constituted the majority of these out-of-state, recreationally-oriented vehicles with values of 32.6, 43.6, and 45.2% of the total percentages for weekdays, weekends, and holiday weekends, respectively. Thus, it appears that increase in traffic in Union County on weekends and holiday weekends is related to an increase in out-of-state, recreationally-oriented vehicles.

In the questionnaire sent to the Union County residents, the respondents were asked to express any comments that they felt appropriate. Many people wrote concerning their fear that the Brookville Reservoir was going to create an increase in traffic volumes and that this increase would be composed of out-of-state vehicles, especially Ohio vehicles. Concern was expressed in regard to the use of Union County funds to repair county roads damaged by out-of-state vehicles. Table 2 appears to substantiate these fears.

Visitor Survey—A total of 957 completed questionnaires was received from the visitors to the Brookville Reservoir. Of these, 307 were received for weekdays, 327 for weekends, and 320 for holiday weekends.

Although Brookville Reservoir is located in Indiana, over half (53.9%) of the visitors surveyed were from Ohio. This value is extremely close to the 55% reported by Nelson and Barrett (4) during the summer months of 1975. These findings vary considerably from the 75% to 80% estimates constantly mentioned by

TABLE 3. *Frequency distribution regarding how far visitors traveled to reach the Brookville Reservoir*

Distance	Frequency	Percent
Less than 10 miles	94	9.9
10-25 miles	204	21.5
26-50 miles	380	40.1
51-100 miles	222	23.4
More than 100 miles	48	5.1
Total	948	100.0

Union County residents. It was never discovered where their estimates originated. However, based on our findings and those of Nelson and Barrett (4), it is felt that 55% is an accurate estimate.

Of those people surveyed at the Reservoir, only 1.3% were from Union County. Franklin County, which also contains a portion of the Reservoir, accounted for 10.4% of those surveyed. Although Franklin County has a larger population than Union County (16,943 compared to 6582 persons (8)), the difference is not proportional to the difference found between the two counties in their number of visitors to the Reservoir. Thus, it appears that Union County residents are experiencing the negative impacts of the Reservoir without sharing in its advantages.

Table 3 summarizes the distances traveled by visitors to reach the Reservoir. The highest percentage (40.1) of people traveled from 26-50 miles to reach this facility. Interestingly, these data represent a normal distribution curve.

Table 4 summarizes the various activities engaged in by visitors. The column entitled "Rank" is the rank that each activity held in our survey. It should be noted that the rankings were exactly the same in both surveys.

Responses to the question asking visitors where in the Reservoir area they had made purchases revealed that 107 (11.2%) of the vistors made purchases in Union County. In contrast, 433 (45.2%) made purchases in Franklin County. Of all the visitors that traveled through Union County, 82 (25.4%) made purchases in Union County. However, 140 (43.4%) of those individuals traveling through Union County made purchases in Franklin County. It appears that many individuals wish

TABLE 4. *Frequency distribution and ranking of activities engaged in by visitors to the Brookville Reservoir*

Activity	Frequency	Rank	Nelson and Barrett (4)
Swimming	807	1	1
Picnicking	505	2	2
Sight-seeing	432	3	3
Boating	345	4	4
Camping	317	5	5
Fishing	270	6	6
Water Skiing	200	7	7
Hiking	124	8	8
Sailing	40	9	9

to arrive at their destination before they stop to make purchases; since the beach and campgrounds are in Franklin County, Union County is deprived of this commerce. In addition, 50.0% of the respondents stated that they were not willing to travel more than five miles to make use of the various stores and services available in the area. Unfortunately, Liberty, the commercial center in Union County, is nine miles from any present beach or campground site. Thus, Union County must bear a large proportion of the Reservoir traffic and receive little in the form of visitors' dollars in return.

Resident Survey—Residents of Union County were surveyed to determine their perception of and desires for the future of both the Reservoir and the county. Of the 800 questionnaires mailed to residents, 203 (24.4%) were returned. These returned questionnaires represented 9.6% of the total number of households in Union County according to the 1970 Census (8). A comparison of returns to the actual population residing in those townships indicated that the sample was representative.

Mean responses were calculated for the questions dealing with population growth and housing development within the county. It was revealed that the majority of the people wished to see the population of Union County grow at less than 30 persons per year, i.e., less than 0.45% per year.

Table 5 lists the frequency associated with the various factors listed on the resident questionnaire. Residents indicated a preference for commercial development concentrated in towns rather than dispersed over the county. In contrast, preferences for housing were divided between those favoring dispersed versus concentrated development. We believe that this division of opinion represents the desire of current residents to maintain their present options for housing, i.e., represents a cultural aspect of this rural community. Residents were also asked to assess the desirability of change in other areas of Union County if it continues to

TABLE 5. *Response frequency for the degree of desirability associated with the various factors listed on the Resident Questionnaire*

Factor	Response				
	Very desirable	Desirable	No opinion	Undesirable	Very undesirable
Dispersed housing	22	78	19	46	37
Housing concentrated in towns	36	100	21	32	10
Dispersed commercial development	25	65	12	61	35
Commercial development concentrated in towns	37	122	13	17	8
Expansion of water facilities	41	73	22	34	29
Expansion of sewage facilities	33	70	25	36	34
Loss of natural areas	10	8	14	64	105
Loss of agricultural lands	4	7	6	41	113

grow. The majority ranked the expansion of water and sewage facilities as desirable and the loss of natural areas and agricultural lands as very undesirable.

In summary, the investigation indicates the importance of long-term planning if a local community is to benefit from large federal projects. Our results show that residents of Union County are experiencing significant social impact from the Brookville Reservoir without enjoying the recreational or economic benefits associated with this facility. Planning efforts in the future must understand better the interface between major federal projects and the local environs in order to minimize negative social impact and to provide long-term socio-economic benefits.

Acknowledgments

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Variations in Petrographic and Depositional Characteristics of Lower Millersburg, Hymera and Bucktown Coal Members in Indiana

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Introduction

The Lower Millersburg and its stratigraphic counterpart, the Hymera (No. VI) coal, are two major mineable seams in the Dugger Formation. These seams vary considerably in terms of thickness and structure not only among themselves but also with respect to other seams which are in very close stratigraphic proximity. The present study is designed to investigate various qualitative variations in these seams in order to understand their correlation.

Geologic Setting

Stratigraphy:

The Lower Millersburg, the Hymera and the Bucktown coal members occur in the Dugger Formation which is correlatable with the upper part of the Carbondale Formation in Illinois.

The Dugger Formation has been considered to extend from the top of the Springfield (No. V) coal to the top of the Danville (No. VII) coal. The Hymera and the Lower Millersburg bearing Dugger Formation occurs in four separate blocks which are scattered in six counties. The Hymera (No. VI) coal, according to the geological literature, occurs mainly in the Dugger Formation of Sullivan, Knox and Northern Gibson counties. The Hymera (No. VI) coal form two northern and southern blocks which are separated in the southern part of Gibson, Posey and Warrick counties. These form two eastern and western blocks. (Fig. 1).

Because no lateral geological demarcation between these two coals has been established, there is particular confusion in Gibson County where both of these coals are reported.

A comparative study of the Dugger Formation in these blocks is presented here. It is beyond the scope of this study to evaluate all the available data in these

TABLE 1. *Characteristics of the Hymera (No. VI) coal bearing Dugger Formation in Sullivan and Knox Counties*

Thickness:	$\bar{x}$ = 121.3 ft.	Depth:	$\bar{x}$ = 188 ft.	Shale/Sand Ratio:	$\bar{x}$ = 6.9:1
	$\bar{s}$ = 16.9		$\bar{s}$ = 60		$\bar{s}$ = 7.8:1
	n = 45		n = 47		n = 23

Limestone: (i) Universal very inconsistent
(ii) Alumcave normally split, a shale band occurs in the middle. Total thickness less than 5 ft.

Nature of the Top: shaley top
occasionally sandy shale

Nature of the Bottom: usually black shale

Remarks: This is considered to be type area for the Hymera Coal.

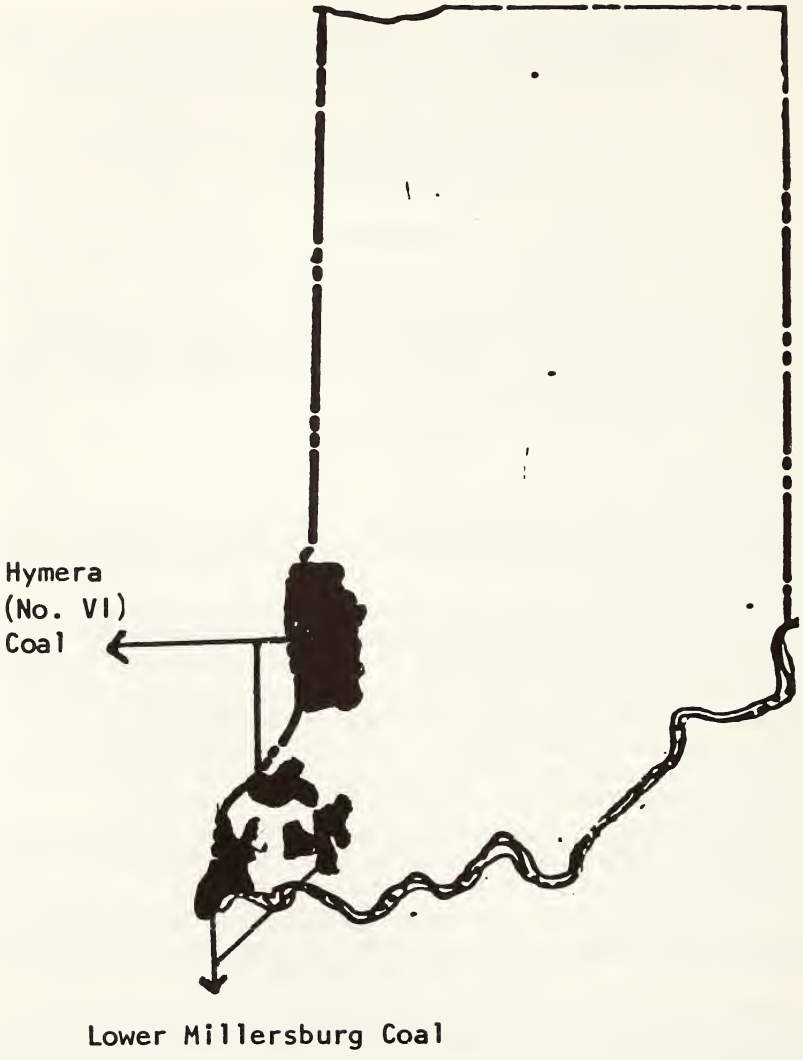

FIGURE 1. *Distribution of Hymera and Lower Millersburg Coal in Indiana*

areas. An effort has been made to maintain the homogeneity of the sample population and also to highlight the geological hetrogeneity in separate blocks.

Characteristics of the upper part of the Carbondale Formation in Illinois:

Lithology of the upper part of the Carbondale Formation which is chronostratigraphically equivalent to the Dugger Formation shows some noticeable variations in lithology. The variations are mainly due to the increasing influence of depth on the sedimentation. Stratigraphic units are usually thicker and relatively more consistent. The interval between the Jamestown (Coal VI in Indiana) and the Coal 7 is is relatively larger. The Bankston Fork Limestone which cor-

TABLE. 2. *Characteristics of the Dugger Formation in Northern Gibson County*

	T.1N.,R.10W.	T.1S.,R.10W.
Thickness:	114 ft.	110 ft.
Depth :	250 ft.	120 ft.

Shale/Sand Ratio: Close to 1:1 ratio in the drill data examined

Limestone: rather consistent limestone bed; Providence present in localized areas

Nature of the Top: sandy shale to shale

Nature of the Bottom: black shale

Remarks: On the basis of the data examined, no discontinuity in the deposition of coal was found. It appears that the Millersburg coals which show a shorter interval between them, compared to the typical VI and VII are the only representatives of that period present.

But the Dugger Formation in general did not show any significant departures from the type area.

TABLE 3. *Characteristics of the Dugger Formation in Southern Gibson County*

	T.2S.R.9W	T.2S.R.10W.	T.2S.R.11W	T.4S.R.10W.
Thickness:	124 ft.	135 ft.	171 ft.	139 ft.
Depth :	103 ft.	174 ft.	294 ft.	165 ft.

Shale/Sand Ratio: Close to 1:1 ratio in the drill data examined

Limestone: rather consistent limestone beds; Providence present in localized areas

Nature of the Top: shale to sandy shale

Nature of the Bottom: black shale

Remarks: No significant difference than the northern part of the county.

TABLE 4. *Characteristics of the Lower Millersburg bearing Dugger Formation in Posey County*

Thickness:	$\bar{x}$ = 258 ft.	Depth:	$\bar{x}$ = 372 ft.
	$\bar{s}$ = 117		$\bar{s}$ = 76
	n = 5		n = 5

Shale/Sand Ratio: 1:1

Limestone: normally well developed; Providence present in localized areas

Nature of the Top: shale

Nature of the Bottom: black Shale

Remarks:

Correlation is very difficult due to:

1. lack of reliable data
2. inconsistent Lower Millersburg
3. well developed Herrin No. 6 coal
4. abnormal variations in depth
5. thickening of strata

TABLE 5. *Characteristics of the Lower Millersburg bearing Dugger Formation in Warrick County*

Thickness:	$\bar{x}$ = 115 ft. $\bar{s}$ = 20 n = 17	Depth:	$\bar{x}$ = 60.2 ft. $\bar{s}$ = 24.4 n = 17
Shale/Sand Ratio:	1.5:1		
Limestone:	(i) Universal relatively more consistent (ii) Alumcave is very thin.		
Nature of the Top:	sandy shale		
Nature of the Bottom:	usually black shale		
Remarks:	This is considerd to be area for the Millersburg Coal		

relates with the Universal Limestone in Indiana is more prominent. The interval between the Jamestown and Coal 6 (Vb in Indiana) is rather irregular. The Anna Shale Member which overlies the Coal 6 in a large area is locally replaced by Energy Shale. Also, in some areas Brereton Limestone or even Jamestown coal directly overlie the Coal 6. The upper part of Carbondale in Illinois is relatively more shaley compared to its stratigraphic equivalent in Indiana.

Coal:

In this study of correlation between the Hymera and the Lower Millersburg coal members, the Herrin and the Bucktown coal seams have also been included. This approach is necessary to establish a qualitative index of variability which will act as a safeguard against any bias of local irregularities. Deterministic characteristics in the four blocks of coal occurrences have been evaluated carefully which are presented in the following pages.

TABLE 6. *Characteristics of the Hymera (No. VI) Coal in Sullivan and Knox Counties*

	T.9N.R.8W.	T.9N.R.9W.	T.6N.R.8W.	T.5N.R.10W.
Thickness:	$\bar{x}$ = 6 ft. $\bar{s}$ = 1.87 n = 4	$\bar{x}$ = 4.9 ft. $\bar{s}$ = 1.2 n = 25	$\bar{x}$ = 5.4 ft. $\bar{s}$ = 0.28 n = 2	$\bar{x}$ = 3.8 ft. $\bar{s}$ = 0.85 n = 17
Depth:	$\bar{x}$ = 86 ft. $\bar{s}$ = 50.2 n = 4	$\bar{x}$ = 159 ft. $\bar{s}$ = 39 n = 26	$\bar{x}$ = 130 ft. $\bar{s}$ = 39.5 n = 2	$\bar{x}$ = 296 ft. $\bar{s}$ = 18.8 n = 17
Roof:	shale	shale	shale	shale
Floor:	shale	shale & underclay	shale	shale & underclay
Split:		consistent 3 x split (50% split occurrences)		coal - upper bench gray shale black shale $\bar{x}$ = 9 ft. gray shale coal - lower bench
Interval between VI and VII:		49 ft.	41 ft.	43 ft.

Remarks: Hymera No. VI coal shows split over a wide range of area. Typically, alternating fresh water and marine water type of depositional environment.

TABLE 7. *Characteristics of the Hymera (No. VI) Coal in Northern Gibson County*

	T.1N.R.10W.	T.1S.R.10W.
Thickeness:	2 ft. (split frequently)	3.5 ft.
Depth:	274 ft.	136 ft.
Roof:	shale	shale
Floor:	shale	shale
Split:	frequently split coal — thin parting coal — thick	
Interval between VI and VII:	24 ft.	16 ft.

Remarks: Interval between the two seams are comparatively closer compared to the Sullivan County. The variations in depth do not follow any regular pattern. Probably reflection of an uneven platform.

TABLE 8. *Characteristics of the Lower Millersburg Coal in Southern Gibson County*

	T.2S.R.9W.	T.2S.R.10W	T.2S.R.11W.	T.4S.R.10W.
Thickness:	4 ft.	3.75 ft.	2 ft.	2.5 ft.
Depth:	124 ft.	198 ft.	275 ft.	175 ft. (insufficient data)
Roof:	shale	shale	shale	shale
Floor:	shale	shale	shale	shale
Split:	occasional (in one case up to 6 ft. of parting)	occasional split (1X)	relatively more frequent	insufficient data
Interval between VI and VII:	21 ft.	20 ft.	20 ft.	insufficient data

Remarks: Very similar to the northern part of Gibson County

TABLE 9. *Characteristics of the Lower Millersburg Coal in Warrick County*

Thickness: $\bar{x}$ = 4.3 ft.
$\bar{s}$ = 1.9
n = 111

Depth: $\bar{x}$ = 71.9 ft.
$\bar{s}$ = 27.2
n = 107

Roof: shale to sandy shale

Floor: shale to underclay

Split: occasional split, usually the parting is less than one ft. thick

Interval between VI and VII: 14 ft.

Remarks: Splitting in the Lower Millersburg coal is prevalent. It is very similar to Sullivan and Knox counties except argillaceous limestone replaces the black shale.

TABLE 10. *Characteristics of the Lower Millersburg Coal in Posey County*

Thickness:	usually very thin or absent
Depth:	418 ft.
Roof:	shale
Floor:	shale - sandy shale
Split:	usually very thin to develop any significant splitting
Interval between VI and VII:	40 ft.
Remarks:	Coal Vb or Illinois 6 is present here with an average thickness of 5 ft. at 524 ft. average depth. The roof is black shale. The interval is maximum here.

The Jamestown Coal Member:

The Jamestown Coal Member of Southwestern Illinois has been considered as a stratigraphic equivalent to the Hymera coal in Indiana. In Illinois the Jamestown coal typically occurs between two limestone units: the Conant and Brereton, with shale beds above and below the coal. Locally, where the Brereton and other members such as the Anna and Energy are missing, the Jamestown approaches the contact of the Herrin (No. 6) coal with only a thin shale separation between them. Towards the deeper part of the basin, the Jamestown becomes very thin and typically black shale replaces the coal. In Indiana the sequence of limestone sedimentations above and below the Coal VI was frequently disrupted.

The Herrin (No. 6) Coal (Illinois) and the Bucktown (Vb) Coal Members:

The Herrin (No. 6) coal is probably the most widely studied coal seam in Illinois and the volume of detailed geological literature on this seam is abundant. The Herrin coal is correlated with the Bucktown (Vb) coal in Indiana. Unlike Illinois, the Bucktown coal in Indiana is thin, inconsistent, a coal seam in the same stratigraphic horizon is prominent in thickness and locally consistent. Similarly, in Vermillion County Indiana, the Grape Creek coal which is in the same stratigraphic horizon is locally thick and consistent. In these two isolated seams of Posey and Vermillion counties, the typical blue band of the Herrin is not present.

Environment of Deposition:

The distribution of the Hymera, the Lower Millersburg and the Jamestown coals in combination presents an elliptical form of depositional system prograding southwestward into the deeper part of the basin. This was probably a trend of delta development during the Hymera and Lower Millersburg time. If we consider that these coal seams are part of the same major depositional system then a chronostratigraphic equality can be established, which is a likely possibility.

The depth and nature of the delta platform was not uniform in all places, which created depositional anomalies to the extent that a discontinuous depositional system prevailed. This entire system is part of the same chronostratigraphic unit. Also, the active secondary channels during this period influenced significantly the final geometry of distribution. The physico-chemical identities of deposition in these sub-basins of the major system are preserved and reflected in the variability of the separate coal blocks, which restricted the lithostratigraphic uniformity among these coals. As proposed by Wanless and others, the thin rock-stratigraphic units of the Pennsylvanian are equivalent to the time stratigraphic units, which is in agreement with this model.

Split:

The Lower Millersburg and the Hymera coals exhibit locally very similar splitting characteristics as can be traced in Knox and Warrick counties.

Coal VI	Lower Millersburg
Coal - Upper bench	Coal - Upper bench
Gray shale	Gray shale
Black shale	Argillaceous limestone
Gray shale	Gray shale
Coal - Lower bench	Coal - Lower bench

If we analyze the situation from an environment of deposition viewpoint, it becomes evident that the gray shale is part of a contemporaneous channel active during that time, and the black shale and the argillaceous limestone belong to a transgressive post coal marine environment. The depth, the nature of the restrictions, and the source materials controlled the type rock deposited.

Petrology

Sampling:

For petrographic study to identify the typical characteristics, channel samples of the Hymera (No. VI) coal from AMAX's Minnehaha Mine and the Lower Millersburg coal from Ayrshire Mines were collected. A drill core sample of the Bucktown (Vb) coal from the Minnehaha Mine area was utilized in this study. ASTM standard methodology was followed in the collection and preparation of the samples for making polished sections (pellets). The pellets were preared in the coal laboratory of Southern Illinois University.

Macerals:

Macerals were identified microscopically under oil immersion using reflected light. More than 2,000 points were counted in each pellet. Efforts were made to delineate the following typical maceral components most prevalent in Illinois Basin coals.

Maceral Group	Maceral
Vitrinite	Vitrinite A
	Vitrinite B
Inertinite	Semi-Fusinite
	Macrinite
	Micrinite
Exinite	Sporinite
	Cutinite

Clay and pyritic materials were grouped separately.

The size and shape of the macerals are generally variable and irregular. In terms of reflectance, two types of vitrinites can be delineated. Inclusions of cutinite and/or semi-fusinite are common. Approximately 30% of the vitrinite macerals contain these inclusions. Mainly thin-walled cutinites are present in the sample. Pyrites and clays are the most dominant accessories.

Lower Millersburg Coal:

The sample studied is from the lower bench of the Lower Millersburg coal, sampled from the Ayrshire Mine area. The maceral sizes appear to be smaller and

angular to subangular in shape compared to Hymera No. VI. Cutinite bands are comparatively more common. Semi-fusinite macerals are more prevalent. Both vitrinite A and B are present and pyrite grains are distributed evenly.

Bucktown (Vb) Coal:

The sample contains angular macerals which are less densely dispersed in the medium. Two types of vitrinites, A and B, occur with inclusion of cutinite and pyrite.

TABLE 11. *Comparison of Maceral Counts*

	VI	Lower Millersburg	Vb
Vitrinite %	96.9	93.1	93.51
Fusinite %	0.4	–	–
Semi-fusinite %	0.8	2.91	3.19
Macrinite %	–	–	–
Micrinite %	–	–	–
Sporinite %	trace	–	1.0
Cutinite %	0.5	0.3	1.1
Clay %	0.86	2.7	0.9
Pyrite %	1	1	1.2

This represents counts of measurable maceral components. The inclusions of semifusinite, cutinite and other mineral components within macerals are not considered here. (Figures 2 & 3).

Reflectance:

Reflectance measurements to determine the Mean Ro for each seam were made separately in two polished sections from each seam. In order to keep the percentage variations in any two polished sections from a given seam under 2%, six polished sections from three seams were used to obtain Ro.

The Calibration standards used were synthetic glasses with the following specifications:

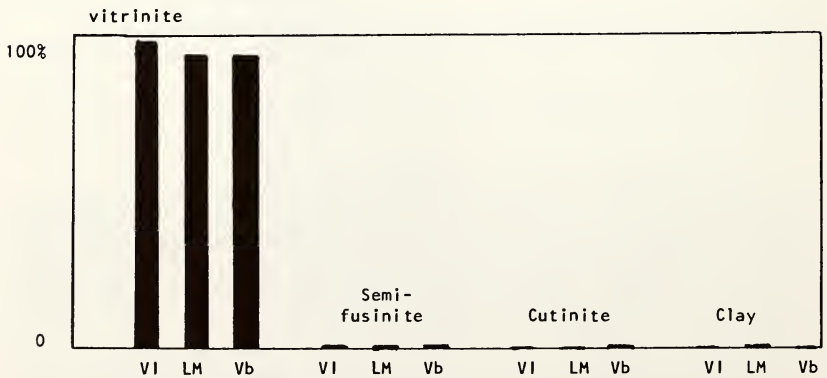

FIGURE 2. *Histogram showing the relative distribution of macerals*

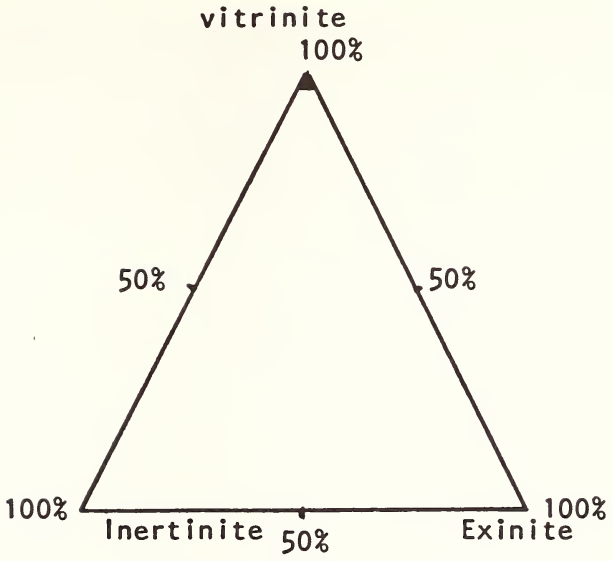

FIGURE 3. *Microlithotypes*

Refractive Index	Reflectance
1.757	0.532
1.856	1.007

Results are as follows:

Lower Millersburg Coal (vitrinite reflectance)

Ro (1)	Ro (2)
$\bar{x}$ = 0.4582	$\bar{x}$ = 0.4663
$\bar{s}$ = 0.0430	$\bar{s}$ = 0.0460
n = 26	n = 25

Hymera (No. VI) Coal (vitrinite reflectance)

Ro (1)	Ro (2)
$\bar{x}$ = 0.4747	$\bar{x}$ = 0.4797
$\bar{s}$ = 0.0364	$\bar{s}$ = 0.0415
n = 27	n = 25

Bucktown (Vb) Coal (vitrinite reflectance)

$\bar{x}$ = 0.4428	$\bar{x}$ = 0.4492
$\bar{s}$ = 0.0248	$\bar{s}$ = 0.0333
n = 28	n = 25
(60 x 120 mesh)	(120 x 0 mesh)

Discussion

In the Indiana geological literature, the Lower Millersburg Coal is typically combined with the Hymera Coal to represent the period between the Danville and

the Bucktown Coals. This approach of correlative combination is logical and fits well in the chronostratigraphic framework. But in the field of commercial extraction, the physical parameters or characteristics which define the lithostratigraphic uniformity need to be properly identified for the commercial market.

An approach to resolve this problem of correlation is to assess the probable geological situations related to the contemporaneity and homogeneity of the seams with respect to the established regional geological framework and the data base provided earlier. Four alternative stratigraphic possibilities are presented here to verify the nature and extent of correlativity.

(i) The seams are chrono and lithostratigraphically equivalent

or

(ii) The seams are not chrono and lithostratigraphically equivalent

or

(iii) The seams are chronostratigraphically equivalent but lithostratigraphically unequivalent

or

(iv) The Lower and Upper Millersburg are split units of one single seam.

The chronostratigraphic equality between the Hymera and the Lower Millersburg can be established by considering the index horizons, their relative position in the geological column, and consistency and order of abundance, which are as follows:

a) Systematic occurences between VII and Vb
b) Position between the Universal and the Providence Limestones
c) Black shale position with Hymera sequence
d) Consistency in the relative position of the seams within each block and also the overall nature of the materials in between
e) Position of the Herrin No. 6 and the Grape Creek coals relative to the Hymera and the Lower Millersburg in two dissimilar geological conditions
f) Similar effects of the contemporaneous channel on both seams indicate the parallelism in time.

In order to establish a lithologic correlation for the coal seams, it is essential to define the boundary values or the limits of variability within which lithostratigraphic equality can be justified. This is critical because of the sensitive nature of the coalification process and the resultant characteristics. However a few observations to assess the lithostratigraphic uniformity are presented below:

a) splitting characteristic (not related to coalification process)—in the Millersburg field the marine transgressive phase is characterized by the argillaceous limestone, whereas in the Hymera coal field area, the corresponding facies is a black shale. This is indicative of the restrictive environments of deposition
b) banded nature—banded nature is predominant in both the seams which can be related to the subsidence or elevation of the water level to control the nature of the vegetation (Marchioni, 1980). Dissimilarities in the banded nature of these seams indicate dissimilar depositional environments
c) An overall similarity in the nature and distribution of maceral composition indicates the same general type of source materials.

In localized areas the upper Millersburg has been reported to be underlain by underclay, which in general represents the end of one independent coal unit. Also,

the presence of the Universal Limestone in localized areas of Gibson and Warrick counties indicates that the Upper and Lower Millersburg are two different coal sequences.

It is evident that the Hymera and the Lower Millersburg are chronostratigraphically equivalent, but on the basis of inequalities in the physical characteristics, these seams can be considered as two independent members of the Dugger Formation. Hence, it would be appropriate to apply the Lower Millersburg nomenclature where its interval with the Danville No. VII coal is less than 25 feet.

Conclusion

The depositional and petrological characteristics of the Hymera and the Lower Millersburg coal members of the Dugger Formation have been systematically analyzed and compared with each individual block of deposits. The results indicate a chronostratigraphic equality for the two different lithostratigraphic units. The suggested model of depositional environment correlates with the physical condition of deposition. It is proposed that in Warrick and Gibson counties, where the interval between the Hymera equivalent (Lower Millersburg) and the Danville equivalent (Upper Millersburg) is less than 25 feet, the Millersburg sequence of nomenclature wold be appropriate to distinguish it from the normal Danville-Hymera sequence. The abnormal reduction of interval in thickness in restricted areas is not uncommon in the Illinois Basin. Similar situations are recognized in the Jamestown-Herrin interval in Clark County, Illinois and the Herrin-Harrisburg interval in the western part of Cumberland County, Illinois.

Acknowledgments

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Geometric and Paleoecologic Analysis of Silurian Reefs near Celina, Ohio

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Introduction

During the summer of 1980 more than 35 small, incipient Silurian reefs were exposed in the vertical walls of the active John W. Karch Stone Co. quarry, which then had an area of about 0.1 square mile and which is 4.5 miles west and 0.5 mile south of Celina, Mercer County, westernmost Ohio (NW¼NE¼ sec. 8, T. 6 S., R. 2 E.) (Figure 1). This reef site is one of many hundreds that are now known to make up the great Silurian reef province that extended throughout the the Great Lakes area and well beyond.

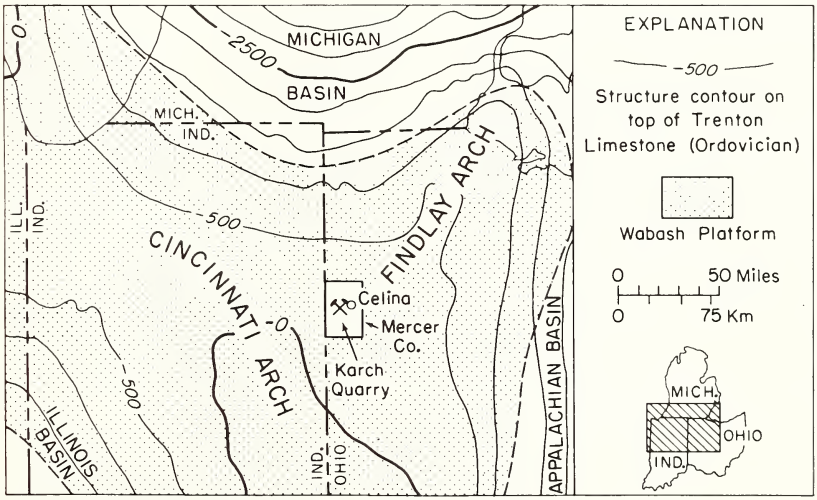

FIGURE 1. *Map showing location of the study area with respect to major present structural features and to the middle Paleozoic paleogeographic feature called the Wabash Platform. Contour interval is 500 feet.*

This province was sustained by several generations of reefs ranging in age at their beginning stratigraphic levels from Early Silurian to late Middle Silurian; a few reefs began to grow at still later times (Droste and Shaver, 5). The archipelago includes reefs that are only a few feet in their major dimensions, other, pinnaclelike reefs that approach 1,000 feet in their vertical dimensions, and reefs in coalesced complexes that extended barrierlike along the margins of the then-developing protobasins.

In the nearly 140 years that have passed since the first scientific notices of these Silurian reefs were published, as much heated debate about their origin,

stratigraphic range, relationship to salt-bearing rocks, and ecologic significance seems to have transpired as concerted agreement has been reached about these same questions. As recorded by Shaver and others (22), explanations of the once-puzzling reef structures have partaken, at one extreme, of volcanic, deformational, and deltaic mudlump theories and, at the other, of involved ecologic theories attendant on so-called true reefs. Although some reports during the past decade seem to have established a vital role for complex organic communities and their capacity to raise wave-resistant structures into relatively shallow water, other reports have minimized the organic-community role by resurrecting and modifying deep-water (even below the photic zone) theories, for example, the reports by Pray (18), Lehmann (13), and McGovney (16).

The Silurian reefs have been highly altered (dolomitized, recrystallized, changed in volume, and even structurally changed to some extent), but we speculate further as to why as much debate as agreement has attended the reefs. As suggested above, the Silurian reefs of the Great Lakes area actually embrace a great range of stratigraphic, paleogeographic, tectonic, sedimentologic, and ecologic circumstances. Such realization is relatively new, and it contrasts with a still common belief that, except for some Early Silurian reefs, all the reefs are Niagaran (Middle Silurian) in age and wholly predate the Middle to Late Silurian salt-depositional episode.

The discussion above puts our Celina reef study in perspective. Beginning to grow during late Salamonie deposition (Middle Silurian), the Celina reefs represent the beginning stages of growth of reefs that constitute probably the largest single generation of Silurian reefs in the Great Lakes area. For example, this generation apparently includes most of the large pinnaclelike reefs that long have been asssociated with hydrocarbon production in the Illinois and Michigan Basins. Opportunities to observe directly the initial stages representing this generation are rare. All the Celina reefs, however, were aborted relatively soon after their inception, which allows us to appraise the environmental circumstances that led to abortion and to observe their direct effect on the reefs.

Our purpose is to set forth the stratigraphic, lithologic, faunal, geometric, and environmental relations of the Celina reefs and to propose their fit in the Silurian paleogeographic scheme that is still unfolding for the Great Lakes area.

Methods

We have separately and intermittently conducted fieldwork in the John W. Karch quarry at Celina (Figure 2) for more than a decade. The most recent concentrated effort was by Griest (9) during parts of the summer and fall of 1980, when he gathered new data on which to base his graduate research report as one of the requirements for the Master of Arts degree in geology at Indiana University, Bloomington.

The entire expanse of quarry walls, developed at two levels, was measured, oriented by Brunton compass, and laid off in sections that hereafter are called transects and that are defined by numbered stations (Figure 2). Sketches, photographs, measurements, and notes were taken in the field for both reef and interreef rocks; fossils were collected from both reef and interreef facies and later identified in the laboratory; and interpretation and preparation of the report completed our work.

As will become apparent, the presence of two quarry levels, one set well back from the other, required that much of our data collecting and analysis be expressed in somewhat artificial terms. Although the quarry division conforms to no strati-

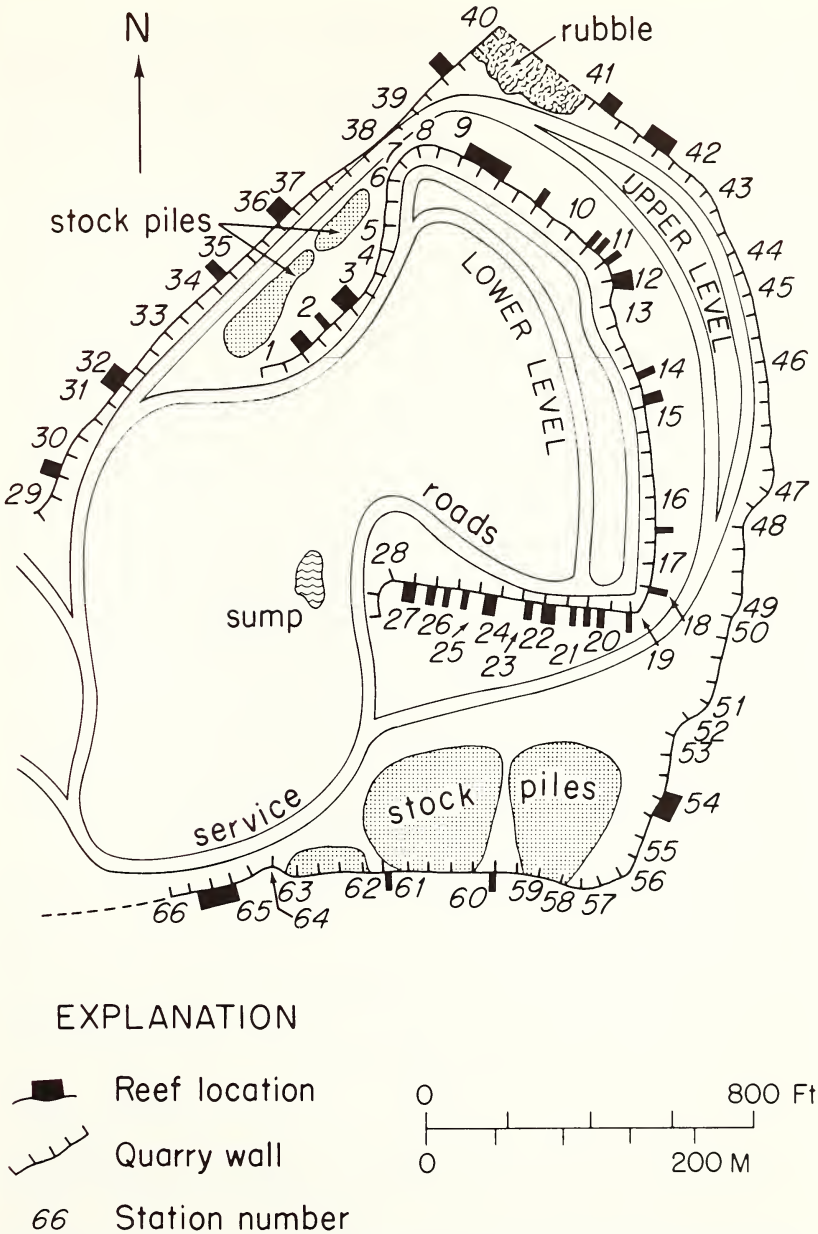

FIGURE 2. *Map of the John W. Karch quarry near Celina, Ohio, showing locations of stations and reef exposures in the walls in the summer of 1980.*

graphic discontinuity, we could not completely integrate the two sets of data. Nevertheless, the difference between the two levels of observations reveal in themselves an evolutionary reef development and related sedimentational record.

Regional Setting, Paleogeography, and Sedimentation

The quarry is near the junction of two present major positive structural features, the Cincinnati and Findlay Arches (Figure 1). This structurally high siting together with erosion has brought to exposure a critical interval of Middle Silurian rocks that are hundreds of feet below the land surface within a hundred miles in any downdip direction and northwestward along the crest of the Cincinnati Arch. Southward these rocks have been eroded.

The paleogeographic setting was hardly the same, as the then-developing basins and arches had not reached their present definitions. Western Ohio was part of a large middle Paleozoic shallow-water area called the Wabash Platform by Droste, Shaver, and Lazor (8). This platform may have been covered nearly continuously by marine waters from late Early Silurian time until Devonian time and during that time may have generally subsided to accommodate reefs several hundreds of feet thick. Alternating periods of pure skeletal carbonate deposition and mixed carbonate and terrigenously derived clastic deposition ensued on the platform during Middle and Late Silurian time. During part of the time pertinent to our study, the Celina area received nearly 100-percent bioclastic carbonate sediments as part of a remarkable deposit, hundreds of feet thick in places, extending from New York and Ontario (Lockport Group and Amabel Formation), and from West Virginia (McKenzie Formation), to Michigan and Ohio (Niagara and Lockport Groups), and to Indiana and Illinois and beyond (Salamonie and Joliet Dolomites and St. Clair Limestone). (See the correlation chart in Shaver and others, 22.)

Particularly during the latter part of this deposition, thousands of reefs began to flourish on the platform and in the linear areas separating the platform from the protobasins. Judging from the great vertical dimensions of the so-called pinnacle reefs fringing the Illinois and Michigan Basins, the protobasins probably subsided more rapidly than the platform did. Near the end of Middle Silurian time, the proto-Michigan and proto-Appalachian Basins (Figure 1) became evaporite basins that then received, in the Michigan example, more than 2,500 feet of alternating carbonate and evaporite rocks during the rest of Silurian time.

The reefs fringing the evaporite basins were soon aborted in the cyclically restrictive environments to which they were subjected. Reefs on the platform variably were aborted, experienced cyclical growth, or continued to grow virtually uninterrupted until Devonian time, depending on favorable or unfavorable locations in a not yet completely understood paleogeographic setting. The Celina reefs are in the first category, having been relatively quickly terminated with the first advent onto the platform of a restrictive environment that, although ameliorated on the platform, was instrumental in salt deposition in the Michigan Basin. Such environmental incursions on the platform were accompanied by deposition of particularly fine-grained carbonate sediments, including oolites, laminates, and mudstones that are noteworthy for their dearth of recognizable fossils. At Celina these sediments constitute the Limberlost Dolomite and Louisville Limestone, and they are correlated with the lower part of the Salina Group (that is, the salt-bearing rocks of the Michigan and Appalachian Basins).

Some geologists consider this account of paleogeographic setting and history to be controversial. It has been pieced together from many reports that are too numerous to credit here but that include especially reports by Droste and Shaver (4, 5, 6, and 7) and Droste, Rexroad, and Shaver (3), in which further credits are listed.

Stratigraphy

Choice of Nomenclature

Although it is clear from Janssens's (12) Silurian studies in northwestern Ohio that he agrees with our correlations stated above, a modern Ohio-based nomenclature had not been applied in Mercer County, Ohio, to give definition to the four separately distinct rock units exposed in the Karch quarry. These units are, however, readily traced from east-central Indiana (Shaver, 19) and in ascending order are: the Salamonie Dolomite, the Limberlost Dolomite, the Waldron Formation, and the Louisville Limestone (Figure 3). Extending Janssens's (12) correlations one county southwestward, we propose that the Salamonie Dolomite in Mercer County be assigned to the Lockport Group and that the other formations be assigned to the Salina Group, there having equivalency with the informal Salina unit known as the A carbonate. These assignments also accord with the correlations of Droste and Shaver (7).

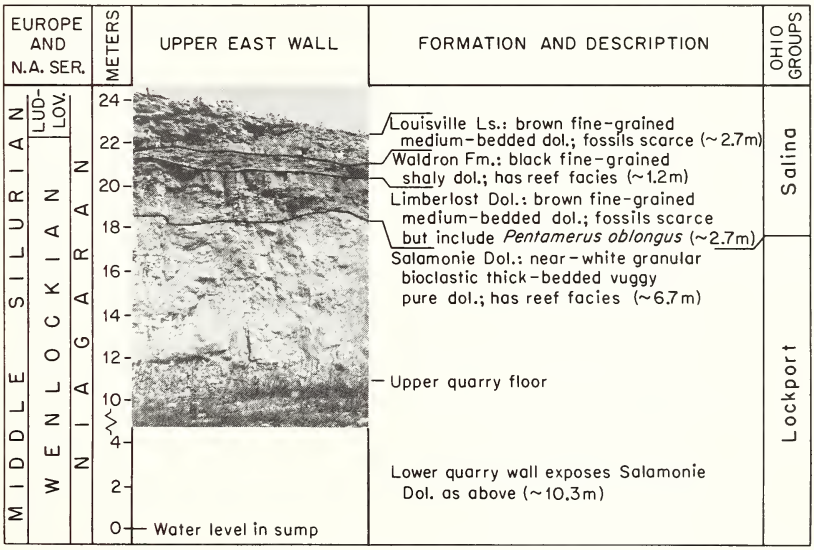

FIGURE 3. *Section showing nomenclature, lithology, thickness, and age of the stratigraphic succession exposed in the John W. Karch quarry near Celina, Ohio.*

Salamonie Dolomite

Only the upper part of the nearly 100-percent pure upper carbonate member of the Salamonie Dolomite is exposed in the Karch quarry. As much as 55 feet (17 m) is observed there to consist dominantly of dolomite that is near white, poorly sorted, fine to coarse grained, medium to thick bedded, vuggy, and bioclastic. Echinodermal debris, most of which is unidentifiable to generic level (Table 1), dominates.

Salamonie Reef Facies

The Salamonie exhibits an incipient but prominent reef facies. This facies consists dominantly of irregular lenses and other geometric forms of blue-gray

TABLE 1. *Register of fossil taxa identified from the reef and interreef facies of the Salamonie Dolomite in the John W. Karch quarry near Celina, Ohio*

Taxon	Lower quarry level		Upper quarry level	
	Reef	Interreef	Reef	Interreef
Unidentified group				
Stromatactid	x		x	
Stromatoporoidea				
Stromatopora sp.	x		x	
Tabulate Coelenterata				
Coenites labiosa (Billings)	x	x		
Favosites sp.	x			
Halysites sp.	x		x	
Heliolites sp.	x			
Rugose Coelenterata				
Arachnophyllum sp.	x			
Neozaphrentis sp.	x	x	x	x
Other nontabulate Coelenterata				
Syringopora sp. A	x			
Syringopora sp. B	x		x	
Bryozoa				
Fenestelloid spp.	x	x		
Unidentified encruster	x			
Brachiopoda				
Atrypa sp.	x		x	
Eospirifer radiatus (Sowerby)	x			
Articulate brachiopod A	x			
Articulate brachiopod B	x			
Gastropoda				
Euomphalus sp.		x		x
Hormotoma sp.				x
Platystoma niagarense Conrad	x			
Cephalopoda				
Lechritococeras desplainense (McChesney)	x			
Phragmoceras sp.	x			
Nautiloid A		x		
Nautiloid B		x		
Crinoidea				
Calliocrinus cf. *C. longispinus* Weller		x		
Siphocrinus sp.		x	x	
Camerate sp.	x			
Crinoid spp.	x	x		x
Cystoidea				
Caryocrinites sp.		x	x	
Trilobita				
Bumastus sp.	x			

massive vuggy dolomitized pure-carbonate mudstone.[1] Such lithology has been observed in the structural cores of large Silurian reefs and has been debated frequently as to whether it also constitutes core rock in the sense of an organic framework. At Celina, the carbonate-mudstone facies contains a highly altered (diagenetically) but recognizable coralline and stromatoporoidal fauna that is distinct from the fauna of the near-white Salamonie facies (Table 1).

The bluish-gray dolomitic lenses have pronounced interdigitations with the near-white dolomite, and in many examples the boundaries are fairly distinct even though bedding from the near-white dolomite can be seen to enter the lenses, where it is lost amidst the massive blue-gray mudstone. (See Figures 4 and 5.) Some bluish-gray dolomite, however, extends outward from distinct lenses across diffuse boundaries with near-white dolomite and extends, in the more extreme examples, hundreds of feet in thin, streaky-appearing intervals of interbedded bluish-gray and near-white dolomite.

The blue-gray lenses have previously been termed incipient reef-core rocks (Shaver, 19). Although they show the intimacy of reef and nonreef rocks, the interbedded streaky intervals are here classified with the interreef rocks. Apart from these intervals, the near-white dolomite (also termed interreef) appears to have no appreciable amount of reef-derived debris, and even the blue-gray material in the streaky intervals could have been generated in place. Some lenses are terminated in the uppermost Salamonie, and some extend upward into the lower part of the Limberlost Dolomite and are there seen to be terminated in all places in the quarry where the Limberlost has not been mostly eroded.

Limberlost Dolomite

The Limberlost Dolomite overlies the Salamonie with conformable contact placed in the middle of a few feet of wholly gradational rocks. It consists mainly of as much as 12 feet (3.6 m) of light-brown fine-grained thin- to medium-bedded very finely vuggy dolomite. Although scarcely fossiliferous in most places, including at Celina, the Limberlost exhibits the highest part of the known range of the Zone of *Pentamerus oblongus*, a brachiopod useful for Silurian-age dating.

In some nearby places the Limberlost and correlative rocks variably have an oolitic facies or a very thinly laminated (algal-controlled?) facies, and in some of these places the Limberlost is associated with reef abortion (Shaver, 19; Droste and Shaver, 4).

Waldron Formation

The Waldron Formation conformably overlies the Limberlost and consists of less than 3 feet to 10 feet (1 to 3 m) of dark-gray (where fresh) fine-grained thin-bedded argillaceous to shaly dolomite. The Waldron has a normal-marine reef facies at Celina and in some other places. At Celina the Waldron reef facies has no relation to the Salamonie reef facies (described above) and is represented by a few small lenslike reefs that were mostly obscured during the 1980 period of fieldwork

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[1] The term carbonate mudstone is used in the sense of what originally was very fine sediment and without any necessary genetic connotation, whether organic related (that is, algal) or not. Thin sections of such material show a uniformly finely granular texture of pervasive dolomitization, just as do thin sections of interreef Salamonie rocks described here as originally poorly sorted and as coarse as coarse grained.

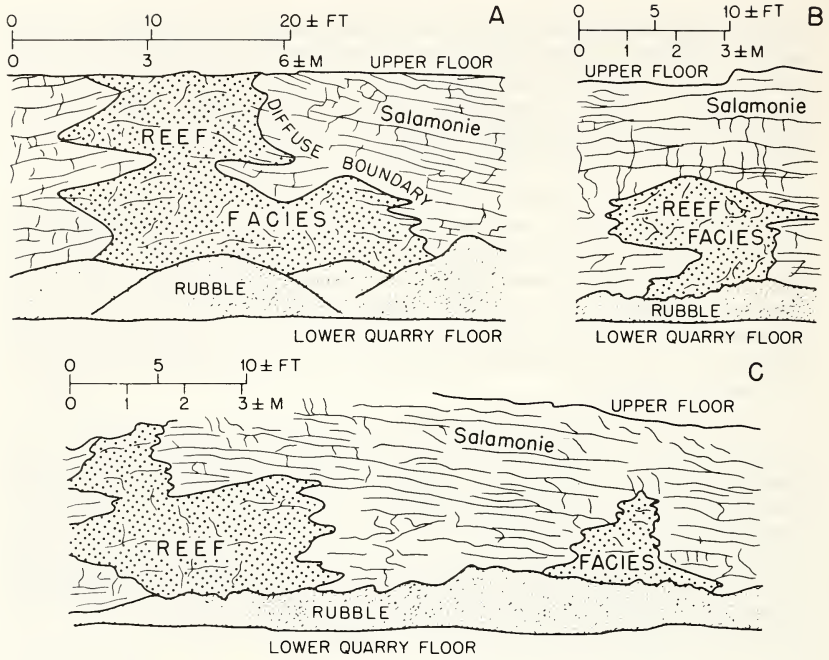

FIGURE 4. *Three nearly normal scale sketches (made by tracing from photographs) of sections along vertical walls of the lower level, John W. Karch quarry near Celina, Ohio, showing reef and interreef relations. A, part of transect 1-2; B, part of transect 16-17; and C, approximately transect 22-23. See Figure 2 for locations of transects.*

by the stockpiles in the southwestern part of the quarry (Figure 2). They are beyond the scope of this report.

Louisville Limestone

The Louisville Limestone conformably overlies the Waldron and consists, where uneroded, of as much as 10 feet (3 m) of brown fine-grained thin- to medium-bedded low-porosity scarcely fossiliferous dolomite. At Celina the upper surface of the Louisville is a glacial pavement, which in places in the Karch quarry has completely truncated both the Louisville and Waldron and much of the Limberlost. As much as 15 feet (4 m) of glacial drift and soil lie above the Louisville.

Reef Geometry

All the identifiable reef exposures at Celina are two-dimensional random cross sections seen in the vertical quarry walls (Figures 2, 4, and 5). Geometry in the third dimension for any given reef is unknown, but any reef is expected to exhibit successively differing cross-sectional shapes and sizes as the walls are quarried back. The actual vertical extent of most reefs is unknown, because at both quarry levels most reefs rise from below the floor, or they are truncated by the upper quarry floor or the bedrock pavement, or both circumstances apply. Whether the reefs tend to be circular, elliptical, or irregular in plan view is unknown.

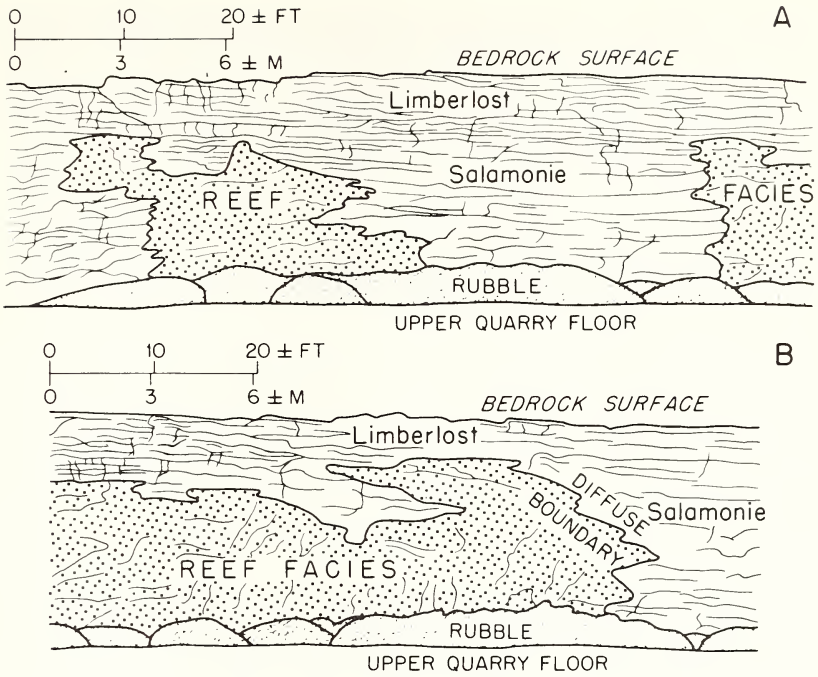

FIGURE 5. *Two nearly normal scale sketches (made by tracing from photographs) of sections along vertical walls of the upper level, John W. Karch quarry near Celina, Ohio, showing reef and interreef relations and abortion of reefs in the Limberlost Dolomite. Parts A and B represent approximately the one continuous transect 41-42, the right end of A joining the left end of B. See Figure 2 for location of transect.*

Nevertheless, a variety of cross-sectional shapes and sizes is evident, one distinguishing character being interdigitation with the Salamonie interreef rocks. Considerable irregularity and asymmetry (unidirectional overgrowth onto interreef sediments) also are evident, so that, altogether, cross-sectional shapes suggest that the reefs would hardly have everywhere supported their own weight. Simultaneous vertical accumulation of interreef sediments at a rate nearly as great as vertical reef accretion is inferred from these cross-sectional shapes.

Only a few reefs appear to have exposed bottom configurations, but some show V-shaped bottom configurations that have superimposed interdigitations and that rise stratigraphically toward the lateral margins of the reef (for example, figure by Shaver, 19, for one of the Celina reefs). A few reefs have coalesced with upward growth, for example, reef masses exposed in transect 1-3 (Figure 2) and as depicted in a general figure by Shaver (19).

As already noted, all the Celina reefs appear to have been aborted while they were still in juvenile stages. Some of the smaller reefs, including those especially in the lower level, terminated through coalescence with larger, ultimately more successful reefs (for example, Figure 4A), or they only may have been unfavorably situated with respect to competitive factors engendered by other reefs or by the in-

TABLE 2: *Register of reefs exposed in vertical walls of John W. Karch quarry near Celina, Ohio, recording locations[1] and sizes.*

Quarry level	Transect	Maximum width		Height[2]	
		Meters	Feet	Meters	Feet
Lower	1-2	8	26		
	1-2	4	13		
	2-3	13	43		
	9-10	31	102	6-7	20-25
	9-10	4	13		
	10-11	2	7		
	10-11	4	13		
	11-12	5	16		
	11-12	9	30		
	13-14	3	10		
	14-15	6	20		
	16-17	4	14		
	17-18	1	3	5	15
	19-20	2	7		
	20-21	6	20		
	20-21	4	13		
	21-22	4	13		
	21-23	7	23		
	22-23	3	10	2	6
	24-25	7	23		
	25-26	2	7		
	25-26	4	13		
	26-27	2	7		
	27-28	7	23		
Upper	29-30	9	30		
	31-33	15	50		
	34-35	6	20	7	26
	35-37	12	49		
	39-40	9	30		
	41-42	10	33		
	41-42	20	66		
	53-55	17	56		
	59-60	2	7	2	6
	61-62	2	7	2	6
	65-66	25	82		

[1] Locations of transects are shown in Figure 2.

[2] Heights are not recorded for those reefs that rise from below the quarry floor, for those whose tops are truncated by the quarry floor or bedrock surface, or for those that are affected by both circumstances.

terreef community. Some of these aborted reefs have rounded tops (for example, Figure 4B). Especially at the higher quarry level, where no reef is known to have grown after Limberlost deposition, the reefs tend to have rounded tops, some much broader and more symmetrical than those shown in Figures 4 and 5, for example, the reef exposed along transect 53-55 shown in Figure 2 (reef itself not figured here).

One massive reef divided at a short vertical distance below its termination and maintained two principal axes of vertical growth thereafter until its final termination (Figures 5A, B).

For reasons now apparent, reef sizes cannot be stated accurately, but maximum widths as seen in the random cross sections of all the reefs located in Figure 2 have been listed in Table 2. These generalities apply: (1) maximum widths range from less than 3 feet (1 m) to more than 100 feet (30 m); (2) the average width is about 24 feet (7½ m); and although the greatest width measured is for a reef seen at the lower level, reef widths tend to be greater at the upper level (averages being about 19 feet, or 6 meters, and about 38 feet, or 11½ meters, for lower and upper levels) (Table 2 and Figure 6).

Reef heights (Table 2) are not amenable to meaningful averagings because the few measurements taken and all those measurements that are lacking are too fortuitous and too dependent on the quarry operation. Most reefs seen at the lower level are truncated by the upper floor, and most of those seen at the upper level rise from below the upper floor, but no reef exposure on either level can be connected with a reef exposure at the complementary level. Although not a single reef can be so proved, the largest ones at Celina probably have heights exceeding the combined heights of the two quarry walls, that is, more than 100 feet (30 m). The least heights are less than 5 feet (<2 m).

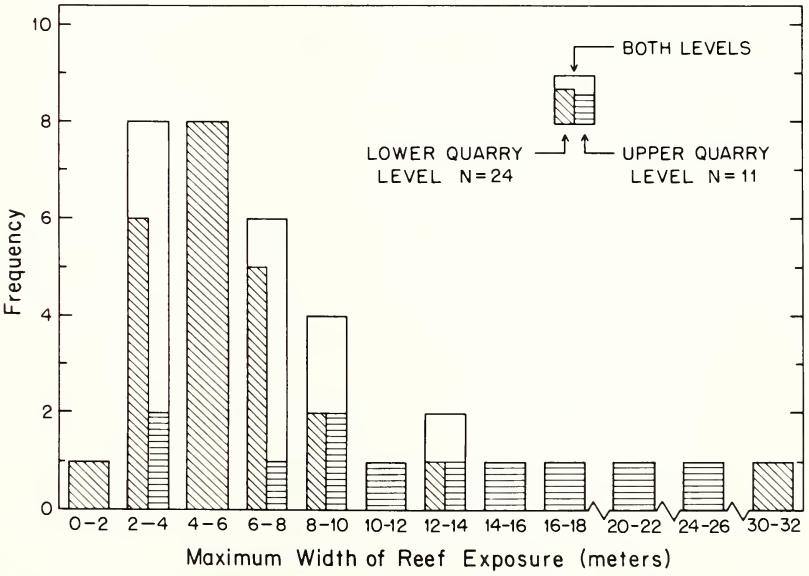

FIGURE 6. *Histogram showing size distribution of reefs exposed in vertical walls of the John W. Karch quarry near Celina, Ohio. See Table 2 for sizes recorded for all reefs.*

Interreef and Suprareef Structure

Regional structure in the Celina area is noteworthy for the near horizontality of sedimentary rock units (Figure 1), but in the Karch quarry bedding attitude is much affected by reefs. Interreef Salamonie strata generally rise toward the reefs at low angles but in some places at angles near 10° (Figure 4). In a few places near the bases of reefs, interreef strata actually dip at low angles toward the reefs. Between closely adjacent reefs, strata generally sag (Figure 5A).

Postreef strata (Salamonie through highest Louisville) are draped over the reefs at low angles similar to those already noted. Where larger reefs are present at the upper level, in the northern and northwestern parts of the quarry, the glacial pavement (bedrock surface) truncates the drape structure, so that in places all bedrock strata younger than lower Limberlost are lacking.

The strata flanking the reefs, although dipping off the reefs, appear to thicken very little or not at all toward the reefs. In this respect, these reef-*flanking* beds differ from reef-*flank* beds that in early all medium-size and large Silurian reefs observed in the Great Lakes area thicken toward the reef core. This observation helps to explain our statement that very little of the near-white Salamonie rocks consists of reef-derived clasts. Also, it explains our characterization of the Celina reefs as *incipient* reefs, because in their particular stage of development they lack bioclastic flank beds that in larger reefs are considered to be an integral part of the reef.

Reef and Interreef Faunas

Although some bias enters into the Salamonie reef and interreef faunal listings of Table 1 — and taxonomic purity is not intended — five significant observations may be made:

(1) The reef fauna is distinctly different from the interreef fauna (Figure 7). It is dominated by so-called reef builders, especially corals, whereas the contemporaneous interreef fauna is echinoderm rich. Moreover, the reef fauna is characterized by greater variety.

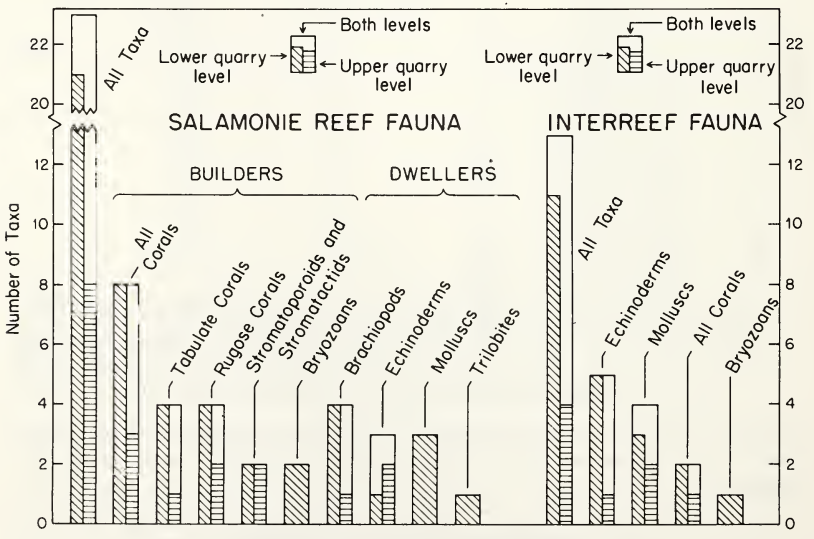

FIGURE 7. *Histograms showing composition of the Salamonie reef and interreef faunas in the John W. Karch quarry near Celina, Ohio. See Table 1 for taxonomic listing.*

(2) The so-called builders (providers of binding) among the reef fauna outnumber the dwellers, a circumstance that indicates juvenility of the reefs.

(3) No faunal zonation in proximal-distal relationship within the reefs was noted, which sets these small Celina reefs apart from Silurian reefs of modest to large size (for example, as described by Indiana University Paleontology Seminar, 10 and 11). This lack is related to the absence of well-developed bioclastic flank beds as integrated parts of the reefs.

(4) Compared with the number of taxa in larger reefs of the Great Lakes area and of higher stratigraphic levels, the number of taxa in the Celina reefs is small. Although more sustained collecting and greater taxonomic rigor than pertain to our study would result in a larger listing, the low taxonomic variety is expectable from the work of Lowenstam (14 and 15) and Shaver (20 and 21). The Celina community, in its low variety, imbalance between builders and dwellers, and relative stratigraphic position, fits well in the earlier and stratigraphically lower end of the peculiarly reef-related evolutionary progressions proposed in the studies noted above.

(5) In the examples of both reef and interreef faunas, a noted reduction in taxa occurs from lower to upper quarry levels. This phenomenon obviously goes hand in hand with the aforementioned reef abortions and the onset of a restrictive environment that led to the faunal scarcity in the Limberlost and, later, in the Louisville rocks.

Because both recognizable fossils and identifiable reef taxa decreases in numbers between the lower and upper levels, even though the reefs increase in size upward (Tables 1 and 2; Figures 6 and 7), it seems obvious that the relative amounts of blue-gray carbonate mudstone (as we have characterized the bulk volume of the reefs) increase upward. Such carbonate mud, completely dolomitized at Celina and in most other exposed Silurian reefs, has long posed an enigma. The dearth of discernible fossils, including algal fossils even when sophisticated methods of detection are applied, has led some persons to propose nonorganic origins, even deep-water origins, of the Midwestern structures we are calling reefs.

Noting the work of Coron and Textoris (1), Suchomel (24), and Lehmann (13), however, we prefer to think that intense diagenesis has obviated ready identification in most Silurian reefs of what probably was a prominent algal role. We suggest, for the Celina reefs, that the carbonate mud was closely related to an algal presence that either trapped or produced (or both) and bound fine sediments. We further speculate that as a group the algae, being more environmentally tolerant organisms, could have survived longer in the increasingly restrictive environment and accounted for the increasing conspicuousness of carbonate mud.

Reef Distribution and Survival

Number of Reefs

Twenty-four discrete reefs were observed at the lower level, whereas only 11 were observed at the upper level even though the upper level affords a greater exposure (Table 1 and Figure 2). The occurrences at both levels were analyzed by means of runs tests to ascertain whether the positioning of reefs relates to random or nonrandom processes. The methods and critical values have been described by Davis (2), Steel and Torrie (23), and Griest (9).

The result was calculated values (-14.83 and -24.73, lower and upper levels respectively) far from the critical value (3.90). The F test described by Davis (2) was used to learn if the lower and upper nonrandom distributions varied significantly. The critical value at the 5-percent level of significance is 1.46,

whereas our calculated F value is 1.37, less than the critical value, which means that the nonrandom distribution values for lower and upper quarry levels are statistically equivalent. We conclude that the Celina positioning is nonrandom. In this conclusion, the reefs may be likened to ecologic systems in general; that is, populations are not randomly distributed but are controlled by complex environmental factors. This finding parallels that of Whiteman and Gardner (26), who applied a so-called near-neighbor analysis to a group of 16 reefs exposed near Lagro in the upper Wabash Valley of northern Indiana. These reefs, with diameters greater than 1,000 feet (304 m) and average spacing of greater than two per square mile, were thought to have nonrandom distribution that would maximize their potential for success.

The original number of reefs at each level (before quarrying) at Celina was established by dividing each level into rectangles and considering that the lengths of quarry walls constitute bases and heights of the rectangles. The product of the number of reefs along the base and height approximates the original number of reefs of a given rectangular area. The numbers extrapolated for the quarried areas as of 1980 for the lower and upper levels are 111 and 30. The number for the lower level becomes 286 when the lower level is figured to have the same area as the upper level had in 1980.

We have mentioned nonrandom positioning in relation to environmental factors, coalescence, and abortion in the onset of a restrictive environment, which in part explain the noted numerical phenomenon, but further analysis is needed.

Lower Level

For the lower level, a size-frequency plot of reefs shows a positively skewed unimodal distribution (Figure 6). The number of reefs increases fairly regularly to nine in the 4- to 6-meter range, six reefs are in the 6- to 8-meter range, and at still greater widths the distribution becomes very irregular. No doubt sampling error is a factor that would have been reduced had reefs been recorded as quarrying progressed through the years.

A survival curve has been constructed (Figure 8) to aid in interpretation. Each reef is treated as one individual or superorganism (Valentine, 25), although in actuality a reef is more like a population of organisms. Further, in this procedure, it is a time-averaged population, because an entire reef from bottom to top at Celina was not living at one time.

The lower-level survival curve (Figure 8) shows an initially high rate of survival in the smallest sizes, followed by low rate in small to intermediate sizes and then by a high rate in the largest sizes. This succession suggests that certain environmental factors prompted the reefs to begin to grow; then increasing competition, whether from the level-bottom communities or from other reefs, resulted in abortion or coalescence; and then the survivors grew to an environmentally stable condition. The validity of this interpretation, of course, depends on the amount of aforementioned sampling error.

Upper Level

The smaller number of reefs observed at the upper level makes interpretation more tenuous. The largest number, three, is found in a small size range, 2 to 4 meters (13 to 20 ft), and at larger sizes distribution appears to be irregular (Figure 6). The survival curve (Figure 8), however, shows an interesting difference between lower-level and uper-level reefs. At the upper level a greater number of size ranges (intermediate to large sizes) are included in the high survival zone. This

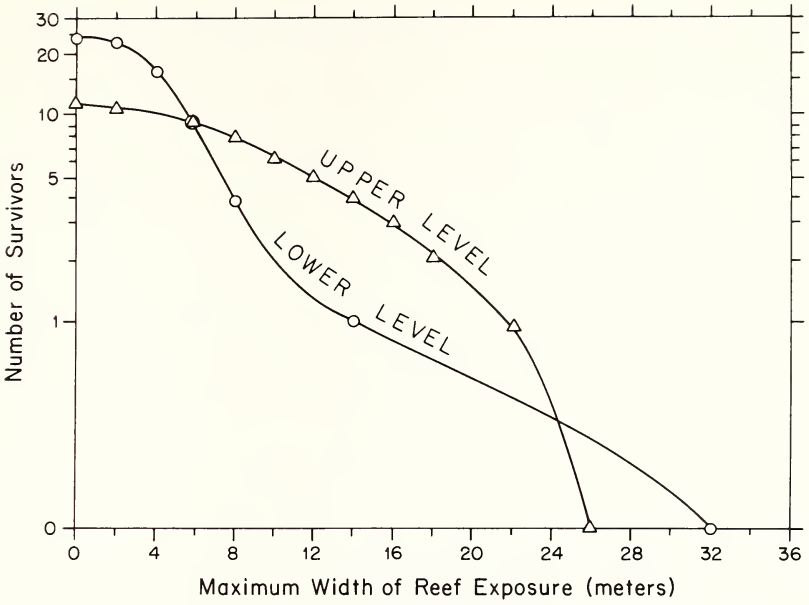

FIGURE 8. *Graph showing the rate of survial of reefs exposed in the John W. Karch quarry near Celina, Ohio.*

observation follows because most upper-level reefs extend upward from the lower level, for which we already noted that larger reefs apparently had reached stability. The low-survival turn of the upper-level curve for the largest reefs (Figure 8) relates to the total abortion of all reefs, apparently with the onset of a generally restrictive environment as was set forth in a preceding section.

Discussion and Conclusions

The Celina reefs belong to a large generation of Silurian reefs that began to grow during the late-depositional phase of a widespread regional deposit that consists of relatively pure and skeletally derived carbonate sediments and that is both blanketlike and banklike in its overall distribution. Well-lit and oxygenated, agitated waters are indicated at Celina, certainly not deep water with its usual connotations. These conditions and other delicately balanced environmental factors, probably including topographic irregularities characteristic of the substrate noted above (for example, megaripples), could have resulted in the initial nonrandom clumping of initial reef masses.

Why these reef starts awaited the latest depositional phase of sediments that in some places are more than 300 feet thick is hardly understood. A critical threshold of shallowing possibly was needed, whatever the overall history of subsidence of the Wabash Platform. The same episode of shallowing could have continued into the time of Limberlost deposition, considering the restrictive, fauna-poor Limberlost environment in which oolite shoals were common and which may have had higher than normal salinity.

In this interpretation,. the Celina reefs appear to be closely parallel to a series of small Silurian reefs in the lower part of the Gower Formation of eastern Iowa.

The Palisades complex there (Philcox, 17) and several reefs exposed in a quarry at Wyoming (Shaver and others, 22), as well as still other Iowa reefs of this generation, have stratigraphic position and sizes very similar to those of the Celina reefs, and they have an abortive geometry brought about by burial in fine-grained carbonate sediments. These sediments, according to Philcox (17), represent a restricted environment, including progressively shallower water that was not more than 30 meters deep initially. This parallel lends support to the thesis of Droste and Shaver (5) that a Great Lakes-wide cyclicity attended the generation and abortion of Silurian reefs and was, synchronously, related to carbonate-evaporite deposition in the Michigan and Appalachian Basins.

The sedimentary features here called reefs are so distinguished lithologically, faunally, and structurally from the contemporaneously deposited level-bottom sediments that little doubt remains of fulfillment of an ecologic definition of reefs. In this conclusion, added meaning is placed on the blue-gray carbonate mudstone that is observed in so many Silurian reefs and that has led some geologists to hedge their terminology with the noncommittal "mud mound" as a substitute for "reef." At Celina this lithology is clearly associated with dominating frame builders, at Celina and elsewhere it is particularly conspicuous in juvenile (incipient) reef cores, and at Celina it makes up the greater parts of reefs that exhibit little or no reef-derived flank rock. The latter observation supports Lowenstam's (14 and 15) concept of initial reef development. The composition of the reef fauna, including the relatively small variety of taxa and the particular dweller-weighted balance, also supports the Lowenstam thesis, as it does the demonstration by Shaver (20 and 21) of a stratigraphically predictable evolution of a peculiarly indigenous reef fauna.

The Celina reefs, ranging in size expressed by exposures a few meters to a few tens of meters wide, have interdigitate margins with interreef rocks such that contemporaneous interreef sedimentation is shown to have proceeded nearly apace with vertical reef growth. Thus, topographic relief of the reefs above the sea floor was modest, never more than a very few meters for even the largest reefs. Some geometry shows asymmetry of growth, some shows coalescence, and some is abortive. The larger, longer enduring reefs have laterally expansive shapes in general, achieved simultaneously with upward growth.

A surprisingly large number of small, essentially point sources for initial reef growth at Celina has been shown. As expectable, considering that reefs were prompted to grow in the first place, the smaller reefs (measured in very few meters) had a high survival history. In larger reefs, abortion had twofold cause: (1) competition among closely spaced reefs (and possibly from the level-bottom community), which resulted in coalescence (abortion of a sort) of many reefs, and (2) the advent of an environment that was unfavorable to reef growth in general, which brought about abortion in the true sense.

For the period following the initial starting phase and during the course of abortion, the reef-survival trend is expressed by a sinuous curve on a logarithmic plot showing a low rate among small (few meters) to modest-sized (several meters) reefs as competition set in and thence a higher survival rate as larger reefs (several to many meters) emerged and became environmentally stable until ultimate abortion from a new cause set in for all reefs.

Should the Celina model of initial reef growth (many initial centers followed by coalescence and reduction in the number of reefs) apply to isolated large, mature reefs hundreds of feet thick covering a square mile or more and apparently having, where observed in their upper parts, a single integrated internal structure? Had

the Celina reefs not been aborted, the next stage would appear to be like that of the Rockford reef complex, which is also in Mercer County, Ohio (Indiana University Paleontology Seminar, 10). No general abortion event occurred there insofar as the preserved rocks show. Well up within the Louisville position, only a single reef clearly dominates the whole, partly integrated complex, although a few other reefs survived to the present level of the bedrock surface within the Louisville interval without coalescence or being overwhelmed by flank rocks of adjacent reefs. The still larger and stratigraphically higher (where quarried) reef at Delphi, Indiana, appears to be wholly integrated structurally where observed 300 to 400 feet above its initial growth position in the upper Salamonie, but coring and other evidence suggest more than one initial growth center (Indiana University Paleontology Seminar, 11).

The answer, therefore, is a possible yes, but additional observations are needed to answer this question fully and other questions that we have not posed here about the rise and ultimate fate of the several Silurian reef generations.

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Oil Occurrence in the Waltersburg Formation (Chesterian) of Southwestern Gibson County

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Over eight million barrels of oil have been produced from the Waltersburg Formation of the study area. Does the production of oil from the Waltersburg Formation come from stratigraphic or structural traps? What is the distribution of reservoir rock within the Waltersburg Formation? What is the origin of that reservoir rock, and is there potential for more oil to be found within the Waltersburg interval in southwestern Gibson County? This paper represents a report of a subsurface investigation designed to answer these questions.

The Waltersburg interval can be mapped between the Menard Limestone above and the Vienna Limestone below. Sandstone within the Waltersburg forms the reservoir rock. The percentage of sandstone within the Waltersburg Formation varies significantly. Structural contour maps on the top and bottom of the Waltersburg interval, and percent and net sandstone maps based on 591 electric logs show that the oil is associated with shoestring and belt-shaped sandstone bodies (1). The oil may be trapped either structurally or stratigraphically.

Figure 1 displays the structural configuration of the top of the Waltersburg Formation. Generally, the top of the Waltersburg Formation dips west-southwest at 40 to 50 feet per mile. In the southeast part of the area the Owensville Fault breaks the structural surface. This fault strikes N20E and is downthrown to the northwest. A southwest plunging anticline is present northwest of the Owensville Fault.

Figure 1 also shows where sandstone thickness exceeds 40 feet. One thin string of sandstone occurs in the northwestern part of the area. This sandstone body coincides with the Rochester oil field shown in black dots. A larger body of sandstone occurs in the southeast part of the area. A large ribbon of sand, from 1 to 1.5 miles wide, trends northeast-southwest across the area and a more narrow, less thick sand ribbon joins the larger along a north-northeast trend. Together these ribbons form a bifurcating pattern.

Based upon the bifurcation geometry in plan view and the common barrel shape of the spontaneous potential logs taken from wells cutting these sandstones, we interpret the depositional environment to be distributary channels of a fluvial-dominated delta system. We must emphasize that no core was available to us.

Three separate petroleum fields produce oil from the Waltersburg Formation of the study area. To the northwest the Rochester field had produced approximately 5.5 million barrels of oil by the end of 1980. The Rochester field is a stratigraphic trap in which the oil is trapped in the northwest (up dip) terminus of a shoestring sand.

In the southeast part of the study area two oil fields are present in close proximity. The Mounts field is the northeasternmost field (Figure 1) and is controlled by the coincidence of the major sandstone belt and structural closure. The Mounts

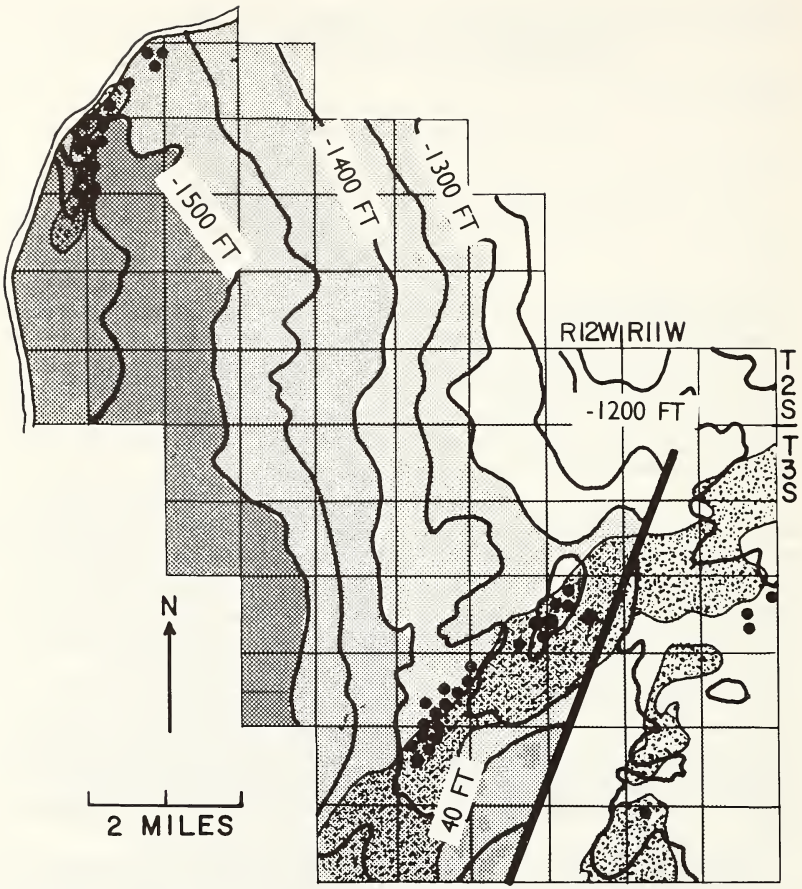

FIGURE 1. *Composite map of the Waltersburg Formation in southwestern Gibson County. The elevation of the top of the Waltersburg Formation is shown by the -1200 ft. to -1500 ft. contour lines. The distribution of the net sandstone exceeding 40 feet in thickness is shown by the coarse stipple pattern surrounded by the line marked 40 feet. Black dots indicate locations of wells that have produced oil from the Waltersburg sandstone. The heavy black line marks the position of the Owensville Fault.*

field is a structural trap that had produced approximately 1.2 million barrels of oil by the end of 1980.

The Fleenor field is the southwesternmost (Figure 1). This field had produced approximately 1.1 million barrels of oil before the end of 1980. The occurrence of oil in the Fleenor field is strange in that the oil appears to be offset down the northwest flank of the southwest plunging anticline. The position might be explained by a) a cementation barrier up dip from the oil field, b) a tilted oil/water contact resulting from hydrodynamics or changes in capillary pressure resulting from

permeability changes, or c) a second fault acting as a seal with negligible slip that would not be recognized by structural contouring. In Figure 1 it can be noted that the southeastern boundary of the field forms a rather straight edge which is subparallel with the Owensville Fault. For this reason we favor the concept of a second fault as being the most likely up dip seal of the Fleenor field. This concept needs to be tested by more detailed mapping of the oil-water contact within the Fleenor field.

In conclusion, oil occurring within the sandstones of the Waltersburg Formation is controlled by both structural and stratigraphic causes. The sandstone body of the Rochester field is distinct and separate from the sandstones of the Fleenor and Mounts fields. Recognition that larger sandstone bodies extend to the southwest and that additional faults parallel the Owensville Fault may provide encouragement for further exploration in the Waltersburg Formation.

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Mineral Matter and Petrography of Microenvironments in the Springfield Coal (V) in Southwestern Indiana

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Introduction

The Springfield coal member (V) of the Petersburg formation along with the stratigraphically equivalent Harrisburg coal (No. 5) of Illinois and the number 9 seam in Kentucky represent the most widespread mineable coal in the Illinois basin (Figure 1). As with other eastern coals, the heating value is very high averaging around 12800 BTU/lb., but the detrimental sulfur content is very high averaging about 3.3% (6). A relationship between sulfur content and depositional environment is well known (4). Low sulfur coals are often associated with contemporaneous sandstone channels and coal with a fluvial gray shale or sandstone roof rock is likely to have a lower sulfur content than coal in the same seam which is overlain by marine or brackish black shale.

Relationships of other mineral constituents and the petrographic constituents of the coal itself with depositional microenvironments are less well known. Depositional microenvironments in the Springfield coal range from nonmarine fluvial to brackish and marine backswamp (1). This study is an attempt to examine coals from these different microenvironments for mineral content and petrographic characteristics to determine if any useful diagnostic relationships exist.

Geologic Setting and Sampling

The Illinois basin is an intracratonic depression encompassing most of central and southern Illinois, southwestern Indiana, and western Kentucky (Figure 1). The basin underwent slow subsidence throughout Pennsylvanian time and was characterized by a broad delta platform resulting from sediment brought in by a large river system from the northeast. As this delta complex advanced across the basin, its fluctuating shoreline often produced a cyclic pattern of alternating marine and nonmarine sediments (7). The delta provided a vast lowland area upon which swamp vegetation accumulated to form peat and ultimately coal.

The Springfield coal ranges from 3 to 13 feet in thickness and extended over almost the entire Illinois basin (Figure 1). The Springfield coal is at the top of the Petersburg formation which is the middle formation of the Carbondale group (Figure 2). The Petersburg formation consists mainly of shales and sandstones which underly the Springfield coal. In places the Springfield coal is partially or completely cut out by sandstone channels. These fresh water deltaic distributary channels apparently represented quite a different microenvironment from the backswamp regions flanking them. Palynological evidence suggests that the flow may have varied somewhat with distance from such channels. The sulfur value of coal deposited near a channel is often considerably lower than that of the rest of the seam (4).

FIGURE 1. *Extent of Springfield Coal (V) and Its Equivalents in the Illinois Basin.*

A total of six sets of samples were collected at two locations in Pike County, Indiana and one in Wabash County, Illinois (Figures 3 and 4). These locations were chosen with reference to their proximity to the major sandstone channels known to cut through the Springfield coal in these areas. Samples 1 (ABC) and 2 (ABC) were collected from Old Ben Coal Company's West Field Pit in Pike County and Samples 3 (ABC) and 4 (ABC) were collected from Old Ben's Alford Pit. Samples 3 and 4 were adjacent to a sandstone channel and samples 1 and 2 were about 4.5 miles from the nearest channels. Samples 5 (ABC) and 6 (ABC) were collected from Amax Coal Company's Wabash mine in Wabash County, Illinois. Sample 5 was adjacent to a sandstone channel and sample 6 was 3.5 miles away from the channel.

At each location three channel samples representing approximately the top, middle, and bottom third of the seam were collected. The only exception was at location 2 where an 8 inch fusain interval was sampled separately as 2F. All part-

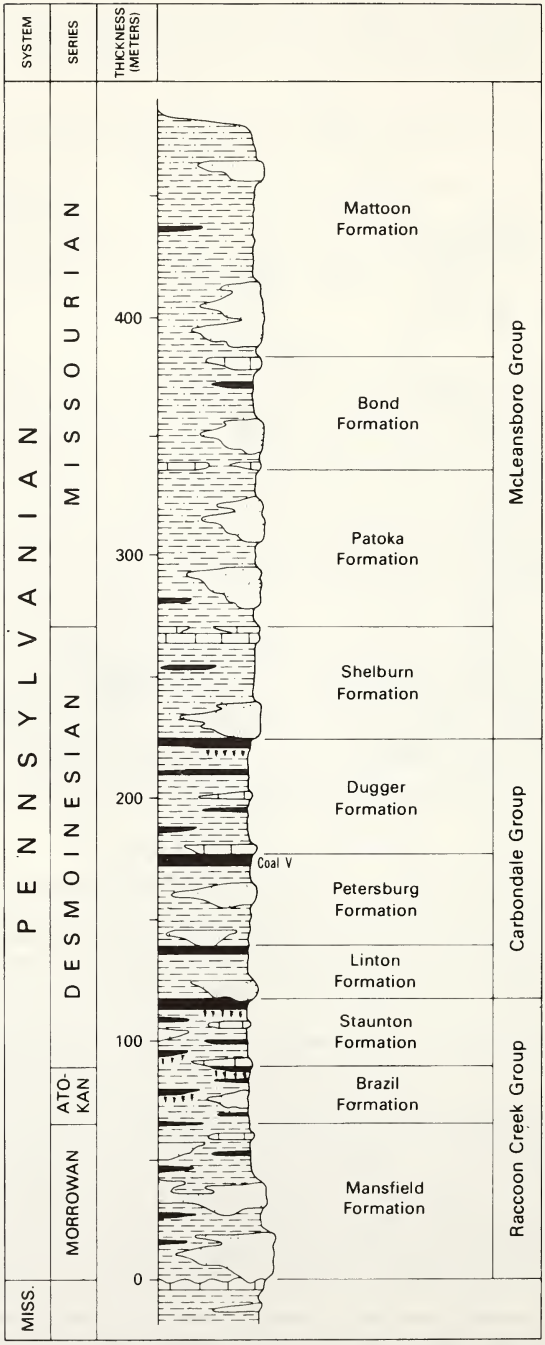

FIGURE 2. *Stratigraphic column of Pennsylvanian Rocks in Indiana (4).*

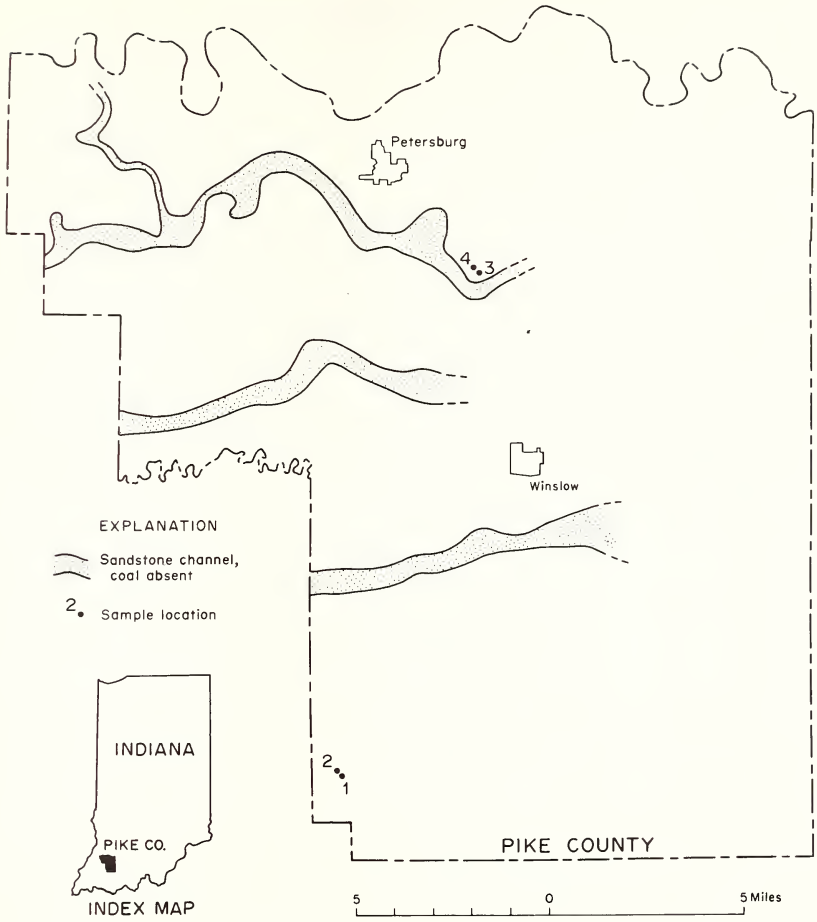

FIGURE 3. *Location of Samples and Sandstone Channels in the Springfield (V) Coal in Pike County, Indiana.*

ings and concretions more than 3/8 inches thick were excluded from the samples but were sampled separately.

Laboratory Procedures

In addition to hand specimens which were crushed to minus 20 mesh and made into polished pellets for petrographic analysis, each channel sample was ground using a very small crusher which automatically separated 20% of the total volume. After splitting the ground sample, the remaining sample was pulverized to a fine powder using a laboratory Raymond mill. About 1.75 grams of each powdered sample were ashed at a temperature of less than 150°C using a Trapeloh TA-504 low-temperature asher. The residue from the ashing process was x-rayed to determine the minerals present.

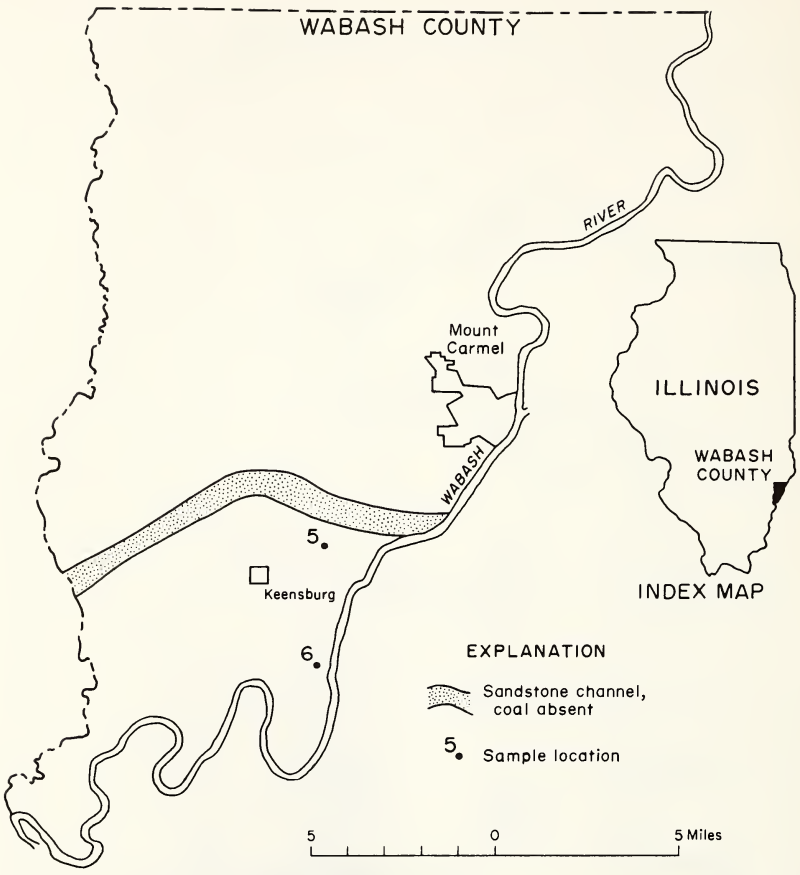

FIGURE 4. *Location of Samples and Sandstone Channel in the Springfield (V) Coal in Wabash County, Illinois.*

The petrographic analyses were carried out according to the combined maceral microlithotype analysis procedure outlined in the International Handbook of Coal Petrography. A minimum of 1200 points were counted on each pellet. From the data the percentages of macerals and minerals, microlithotypes and carbominerites, and the components of individual microlithotypes were determined.

Results and Discussion

The results of the low temperature ashing are shown in Figure 5. With the exception of sample 6 the highest ash percentage is in the top third of the seam followed by the bottom, with the lowest percentage in the middle. The minerals present in the ash were identified by x-ray diffraction and are shown in Table 1. The clay minerals kaolinite, and illite, quartz, and pyrite were present in every sample. In most samples the illite showed a mixed layer component smectite. The highest concentration of the clay minerals were found in the top third or bottom third of the

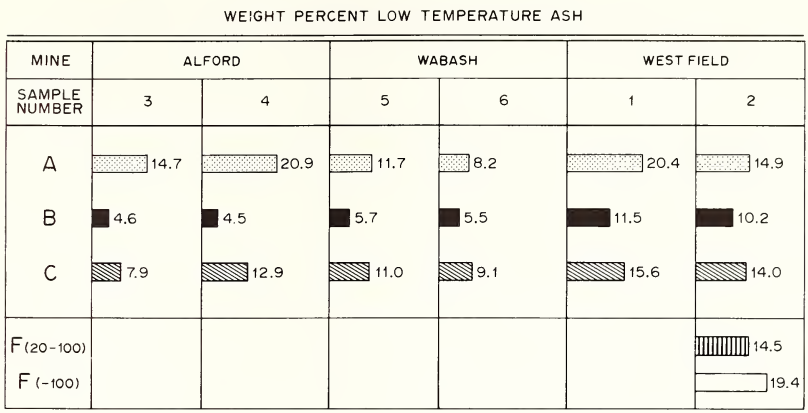

FIGURE 5. *Percentage of Mineral Matter Residue from Low Temperature Ashing.*

TABLE 1. *Minerals present in low-temperature ash samples as determined by x-ray diffraction.*

Sample Number	1A	1B	1C	2A	2B	2C -20	2F -100	2F	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	6C
Qtz.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fspar.	X			X			X		X	X	X	X	X				X	X	X	X
Kao.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ill.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chlor.									X	X		X					X	X		
Pyr.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Calc.	X	X	X	X	X	X	X	X					Y	Y	X	X	X	X	X	X
Dolo.	X															X				
Sid.	X						X	X	X			X			X	X	X			
Ank.									X			X								
Anhyd.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Szom.	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X

Qtz.—quartz; Fspar.—feldspar; Kao.—kaolinite; Ill.—illite (and mixed layereds); Chlor.—chlorite (and mixed layereds); Pyr.—pyrite; Calc.—calcite; Dolo.—dolomite; Sid.—sidzerite; Ank.—ankerite; Anhyd.—anhydrite, Szom.—szomolnokite.

X indicates the mineral is present

Y indicates the mineral is present, but in considerably smaller amounts than elsewhere.

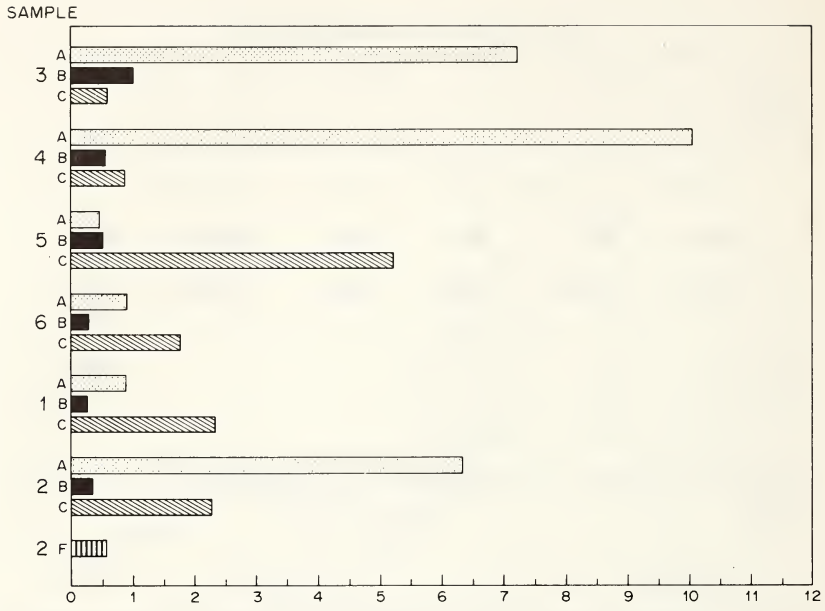

FIGURE 6. *Volume Percent Clay.*

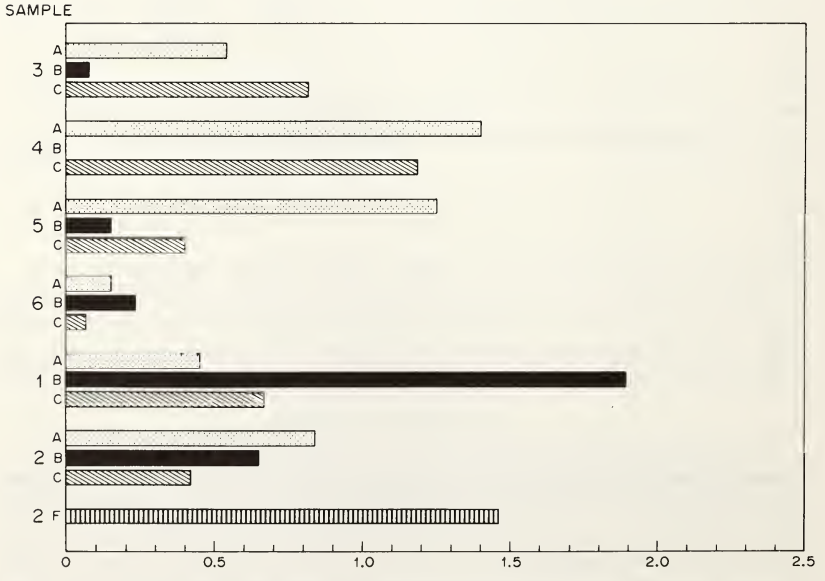

FIGURE 7. *Volume Percent Pyrite.*

seam as shown on Figure 6. Also the amount of clay minerals present decreased farther from the sandstone channel. Quartz was more abundant in the top and bottom third of the seam but was more evenly distributed throughout the seam at locations closest to the sandstone channels.

Pyrite was more concentrated in the top and bottom third of the seams (Figure 7) and the highest concentration of pyrite were found at locations 1 and 2 where the coal was overlain by black shale. The least amount of pyrite was found under gray shale at location 3 and 6. The vertical distribution of pyrite appears to depend on the distance of the sample location from a sandstone channel. Near the channel the pyrite is concentrated in the top and bottom of the seam whereas away from the channel the highest concentrations are in the middle of the seam. Also the form of the pyrite changes with distance from the channel. Away from the channel, there is a change in dominance from tiny euhedral to larger euhedral to framboidal forms. Euhedral pyite grains are shown in Figure 8 and framboidal pyrite in Figure 9. It has been suggested that pyrite takes on a framboidal shape as a result of the activity of sulfate reducing bacteria (5). These cannot tolerate the low pH of fresh water peats (2) and as a result more sulfate reducing bacteria and therefore more framboidal pyrite are found in the backswamp microenvironment.

Calcite abundance is highest in the backswamp areas and lowest near the channel. Its presence appears to be related to the higher pH brackish and marine swamp areas.

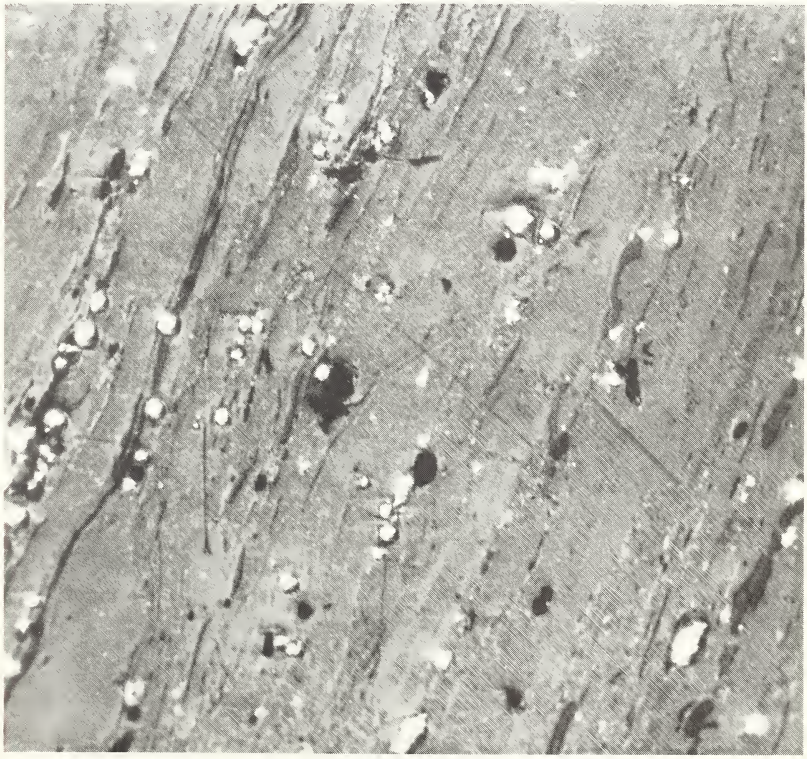

FIGURE 8. *Euhedral Pyrite in Springfield Coal.*

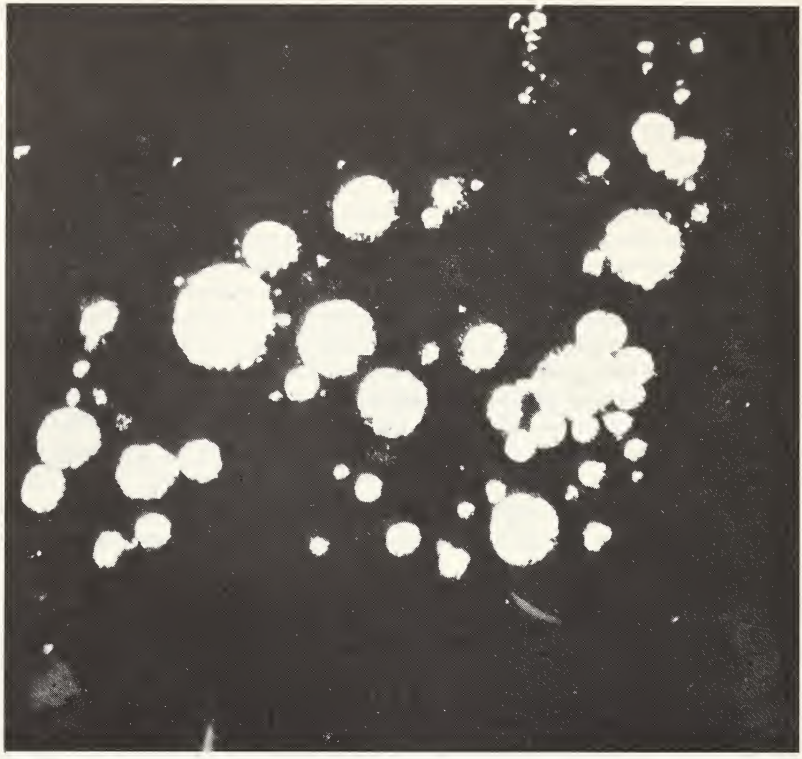

FIGURE 9. *Framboidal Pyrite in Springfield Coal.*

The distribution of the maceral groups helped to formulate a picture of how conditions in the coal swamp varied through time and with distance from the delta distributaries which meandered through the swamp. Vitrinite is by far the most abundant maceral comprising about 90% of most of the samples (Figure 10) which is indicative of a forest swamp environment. The swamp was populated primarily by tree ferns and lycopoda (1), the woody parts of which served as the raw material for the vitrinite. Inertinite abundance peaks in the middle of the seam (Figure 11). Inertinite is a product of the same types of materials which produce vitrinite except that inertinite was subjected to a certain amount of oxidation during the peat formation. The increase in inertinite percentage in the middle of the seam may indicate that there was shallowing and an increased subaerial exposure because of a drop in water level or a build up of peat and organic debris above the water surface. Exinites in general reached their greatest abundance in the top third of the seam. Exinites are composed of such resistant materials as spore exines and leaf cuticles. This would indicate more decay of the woody material and relatively a higher percentage of exinite. As the swamp matured then there would be more frequent subaerial exposure and decay which appears to be the case.

In addition to the vertical variations there was some horizontal changes in relative abundance of the macerals. The exinite content was highest closest to the

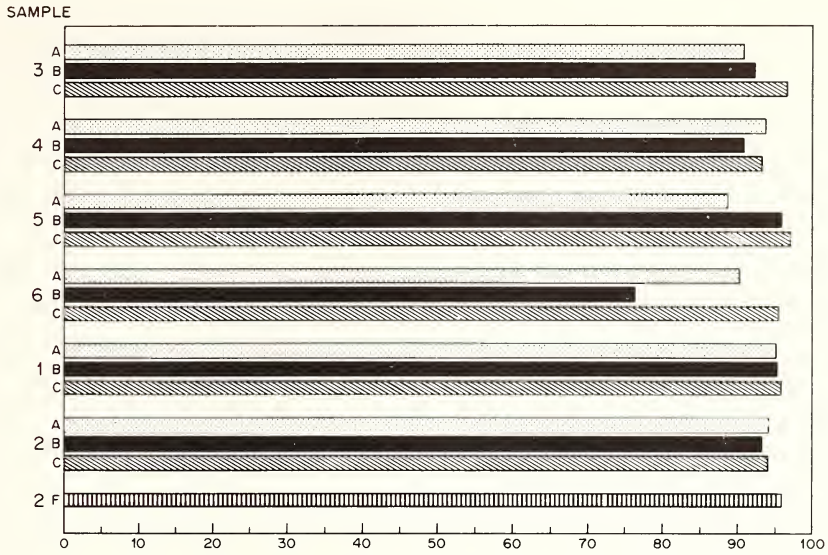

FIGURE 10. *Volume Percent Vitrinite.*

fresh water channels indicating that the more oxygenated water entering the swamp stimulated aerobic bacterial decay of the woody substances leaving a higher percentage more exinite behind. The intertinite content increases with distance from the channel indicating more aerial exposure of the woody material.

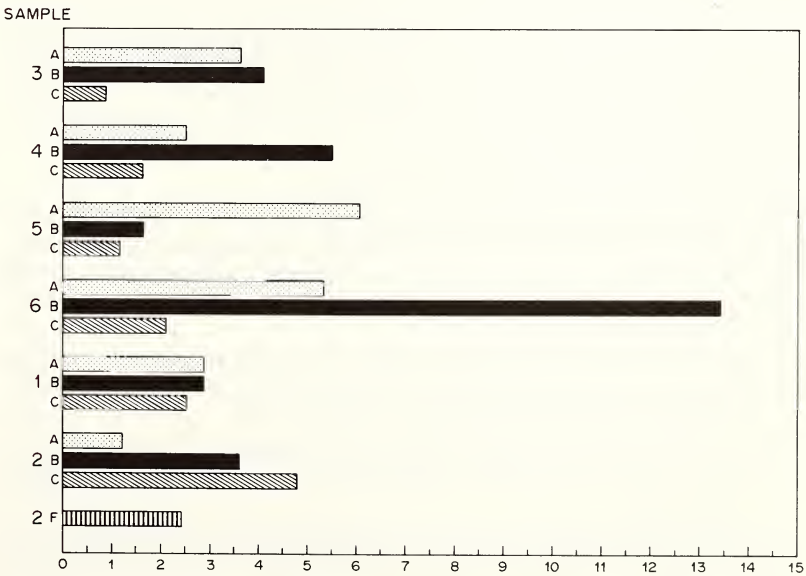

FIGURE 11. *Volume Percent Inertinite.*

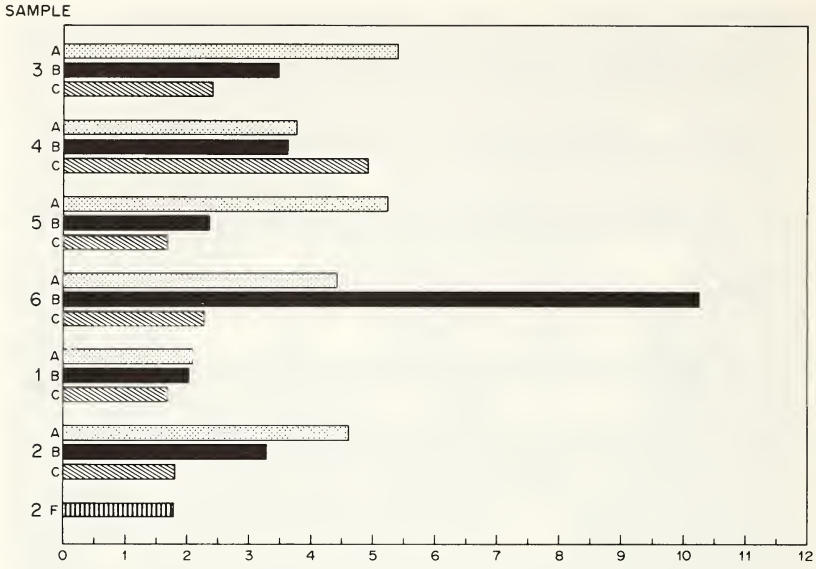

FIGURE 12. *Volume Percent Exinite.*

Conclusions

A detailed microscopic study of macerals and a determination of the mineral matter in coal can provide a better understanding of the microenvironments of deposition in a coal swamp. The relative abundance of the macerals can indicate the water conditions and the amount of subaerial exposure in the swamp as it progressed through time. The detrital mineral matter is highest near the distributary channels and the form of the pyrite changes relative to the distance from the channels with the framboidal pyrite more abundant in the backswamp brackish microenvironments.

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High-Brightness Limestones in Indiana

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Introduction

After the reorganization of the Indiana Geological Survey in the late 1940's, geologists in the Industrial Minerals Section began a systematic investigation of commercial limestone and dolomite deposits. At each active quarry and at many abandoned quarries and prominent natural exposures, geologists measured sections and collected samples for chemical determinations by the Geochemistry Section. Of the the thousands of analyzed samples on file, we selected more than 450 high-calcium limestones for a new study on brightness.

Use of high-purity, high-brightness limestone for filler or whiting applications in the United States in 1979 amounted to more than 1.3 million tons with a value of $32.5 million (18), but none was produced in Indiana despite its central location with respect to markets and premium prices paid for bright stone. Because we felt that some of Indiana's high-calcium limestones (greater than 95 percent calcium carbonate) had properties that would allow them to be used for fillers, we began brightness measurements to determine their suitability.

Thick units of carbonate rocks are abundant near the surface in Indiana. Numerous chemical analyses have shown that high-purity limestones of significant thickness occur in the Paoli Limestone (Late Mississippian), Ste. Genevieve, and Salem Limestones (Middle Mississippian); the Muscatatuck Group (Middle Devonian); and the Wabash Formation (Middle and Late Silurian) (Figure 2). Details on brightness will be reported for specific examples of limestones from Carroll, Orange, and Harrison Counties (Figure 1).

Limestone Fillers

Significant amounts of high-purity, bright limestones are used in plastics (20 percent), rubber (15 percent), paints (20 percent), putty and joint fillers (20 percent), adhesives and floor coverings (20 percent), and paper (<5 percent), where the limestone acts as inexpensive filler, extender, or pigment and to a small degree as a coating (6, 9, 10, 11). As with most industrial minerals, cost is important; location of the deposit with respect to market plays a large role in overall cost of the products. Much filler comes from Georgia, New England, Texas, and Illinois; some Indiana high-calcium limestone, if of suitable brightness, would appear to be favorably situated to markets. Distribution of raw materials and specifications for this use as fillers are outlined by Cummins (7), Key (12), Severinghaus (16), and Wilson and Skinner (19).

Besides very fine particle size, chemical purity and high brightness are essential for fillers (Table I). Generally there should be high amounts of calcite or dolomite (>95 percent) and low amounts of $MgCO_3$ (<2 percent for limestones), silica (<1 percent), iron oxide (<.1 percent), and alumina (<1 percent). Brightness is an important property of fillers; most limestones have brightness >85 percent, although brightness for materials in floor coverings can be in the low 80-percent range. Goodwin and Baxter (8) suggested that limestones with brightness >70 percent should be considered as potential materials for fillers. Other properties, such as particle size and shape, oil-absorption characteristics, and flow properties may also be important (3, 7, 19).

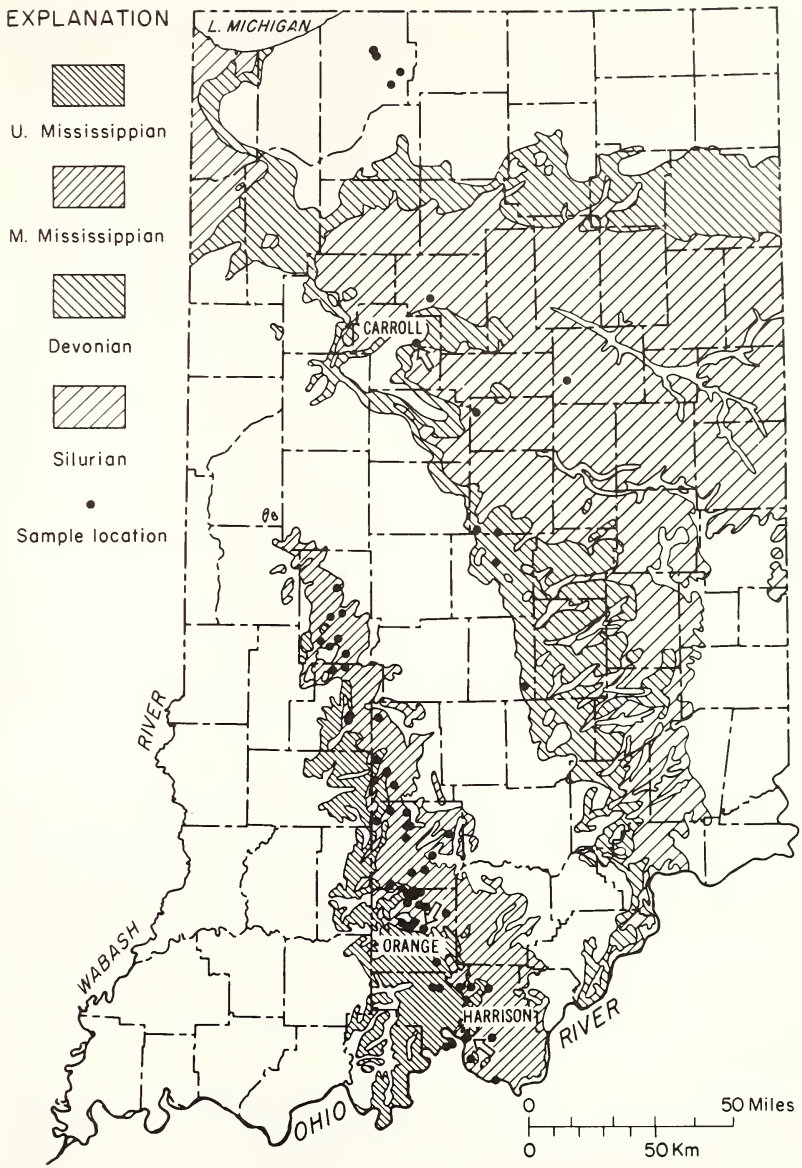

FIGURE 1. *Map of Indiana showing bedrock distribution of geologic units that contain high-purity carbonate rocks and sample sites.*

Brightness

Samples were finely ground (80-90+ percent passing a 325-mesh nylon screen), and the resulting powders were pressed into pellets by using a metal ring,

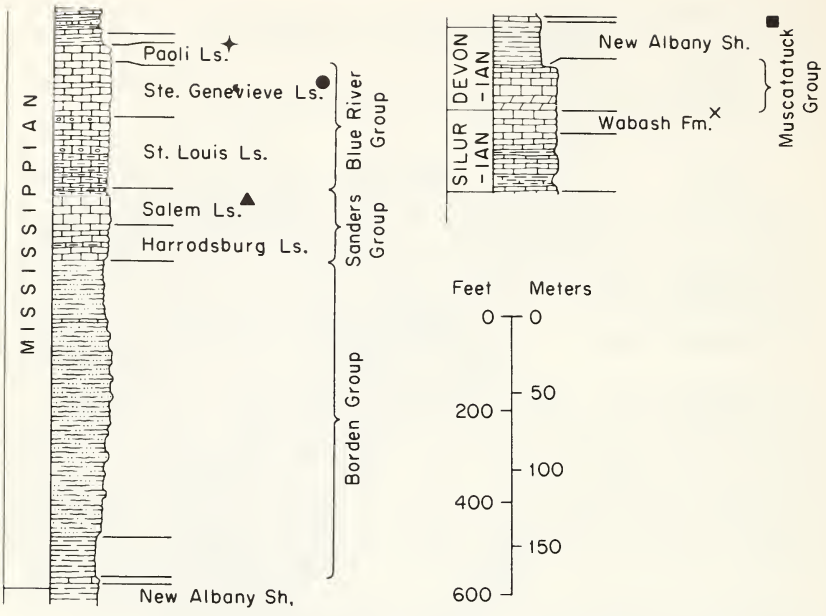

FIGURE 2. *Generalized columnar section showing rock units occurring near surface that contain high-purity carbonate rocks. Symbols refer to sample sites shown in Figure 3.*

plunger, and a smooth, flat glass plate (Figure 4). Pellets were placed on the search unit of a Photovolt 670 reflectance meter, and the amount of light reflected from the powder, relative to a powdered $BaSO_4$ standard furnished by Kodak (99 percent reflectance) and an enamel standard furnished by the manufacturer, was determined. Measurements were made by using blue, green, and amber filters, so that tristimulus color and whiteness, or yellowness, indices could be determined.

TABLE I. *Specifications for commercial fillers as reported by four companies (A, B, C, and D).*

	FILLER SPECIFICATIONS			
	A	B	C	D
$CaCO_3$ (%)	98.0-99.8	98.0	90.96	54.0
$MgCO_3$ (%)	Trace	1.50	0.60	44.0
SiO_2 (%)	–	0.60	1.40	0.5
Fe_2O_3 (%)	0.02	0.05	0.08	0.1
Al_2O_3 (%)	0.10	0.08	0.50	0.4
BRIGHTNESS	88–96	95-98	87-91	94

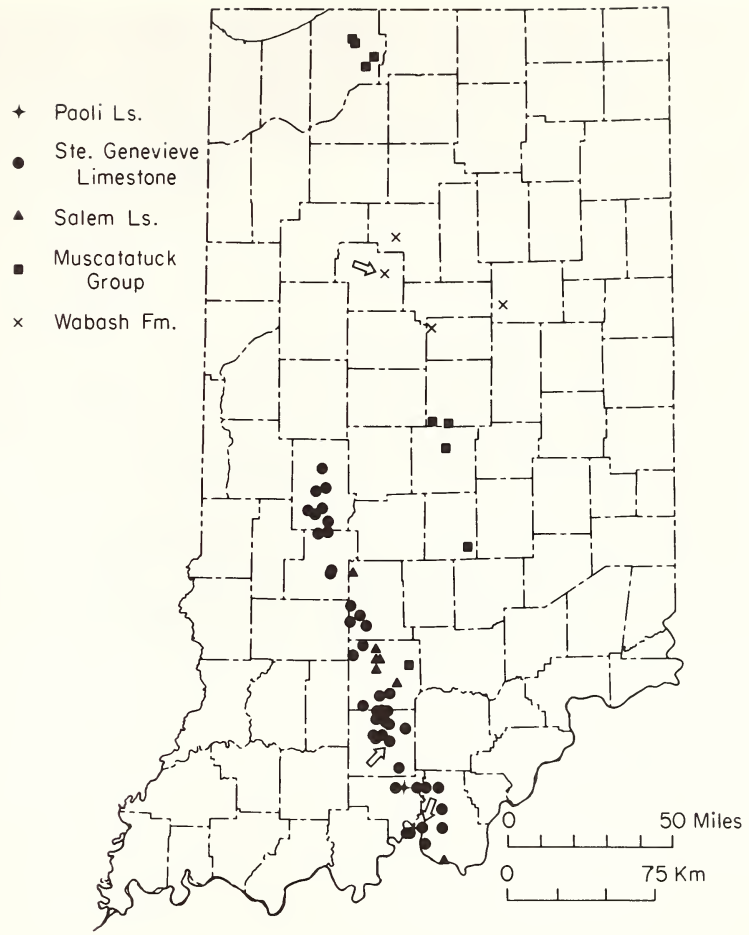

FIGURE 3. *Map showing sample locations. Symbols indicate stratigraphic units shown in Figure 2. Open arrows refer to site locations mentioned in text in Carroll, Orange, and Harrison Counties (north to south).*

This method is a modified version of Pulverized Limestone Association standard 5-68T. Brightness is reported as dry reflectance and was reproducible to ± 0.1 percent on single pellet and about ± 0.5 percent on different pellets. Our measurements compared favorably with other laboratories but showed wider variance because different equipment and filters were used.

A summary of the reflectance measurements for Indiana limestones (Figure 5) clearly shows that some limestones have relatively high brightness values. The samples with highest reflectance values came from the Ste. Genevieve Limestone, which ranged from 67 to 88 percent brightness and averaged 81 percent, and from the Wabash Formation, which ranged from 72 to 91 percent brightness and averaged 82 percent. Disappointingly, but not unexpected, low values were found for the St.

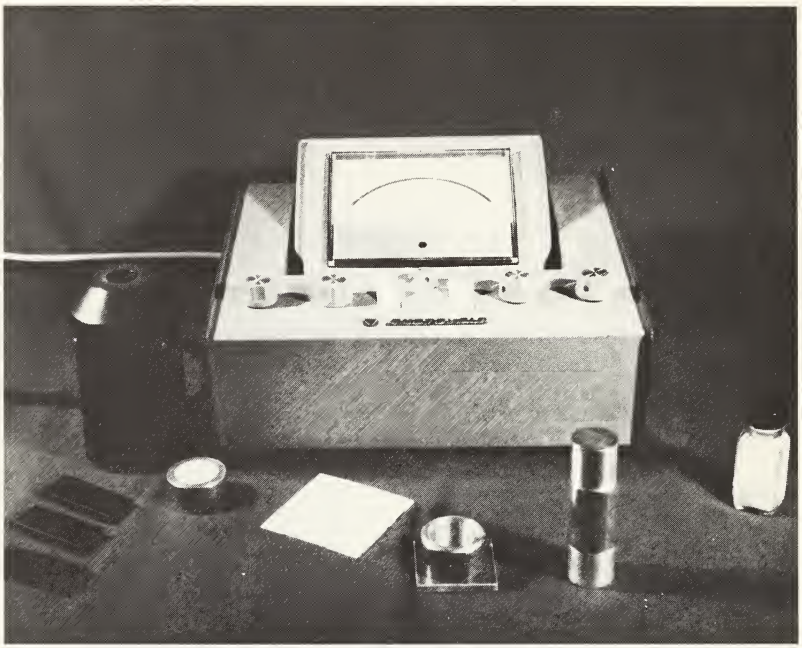

FIGURE 4. *Equipment used to measure brightness. Powder was pressed into pellets, and reflectance through three filters was measured by comparing with standards.*

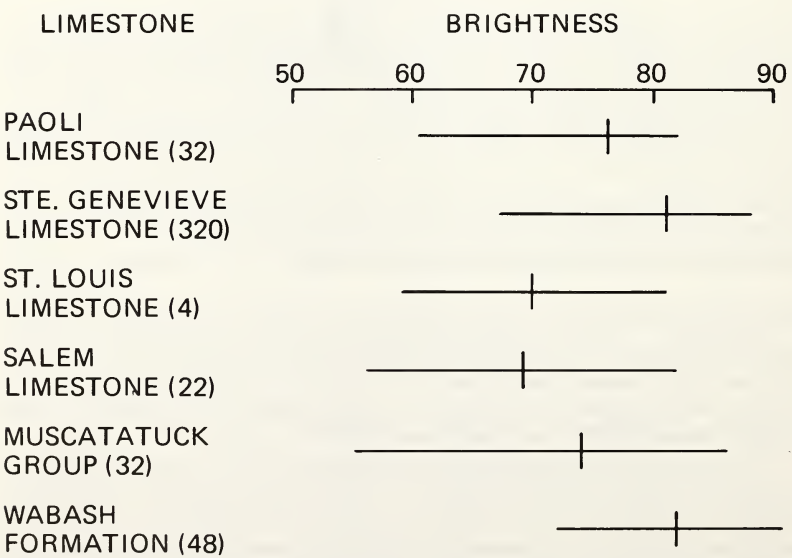

FIGURE 5. *Range and average brightness values of high-purity carbonate rocks from Indiana. Numbers in parentheses indicate number of samples.*

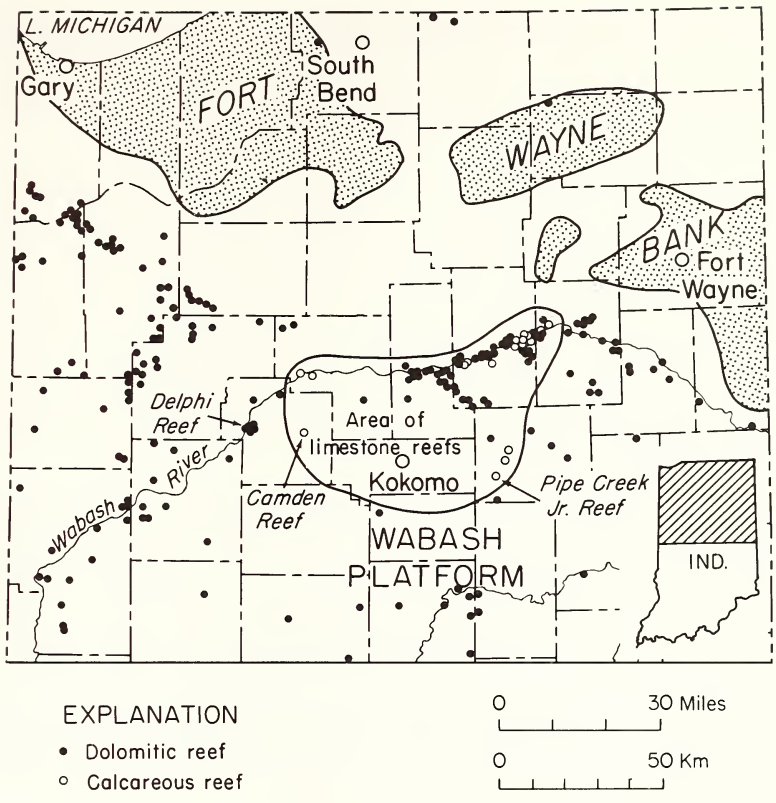

FIGURE 6. *Map of northern Indiana showing locations of known reefs and area of limestone reefs. From Ault and Carr, Figure 3 (2).*

Louis and Salem Limestones, which ranged from 56 to 82 percent brightness and averaged 69 percent. Relatively low values also were obtained for carbonate rocks from the Muscatatuck Group, which ranged from 56 to 82 percent brightness and averaged 74 percent, and from the Paoli Limestone, which ranged from 61 to 82 percent and averaged 76 percent.

Limestones of Silurian and Devonian Age

Thick high-calcium limestone is present in several formations of Devonian age in southeastern and northern Indiana and in a few of the hundreds and possibly thousands of reefs that grew on the broad Wabash Platform that extended through much of northern and central Indiana during Silurian time (Figure 6; 17). Most of the reefs have been dolomitized, such as the reef complex at Delphi and reefs of the Ft. Wayne Bank, but several limestone reefs are known in an area that includes parts or all of several counties in north-central Indiana (1, 2).

The highest brightness values we have recorded for Indiana rocks have come from samples of the more than 250 feet of high-calcium limestone that has been test drilled in a large reef of Silurian age near Camden in Carroll County. A similar reef

in southeastern Grant County at the Pipe Creek Jr Quarry also contains thick high-purity limestone that has commercial potential for high-brightness products. The above two reefs are about 1 mile in diameter at their largest dimensions at the bedrock surface and are more than 300 feet thick. They are mushroom-shaped with their smallest dimensions at their bases in rocks of Middle Silurian age.

Lithologies of the limestone in both reefs are similar. They are mostly high-calcium limestones that are light gray to white and that contain less than 2 percent noncarbonate minerals. The high-purity limestone consists of skeletal material, much of it fragmental, that has been tightly cemented with clear to white sparry calcite in reef-flank beds. Although parts of the reefs are dolomitic limestone or dolomite, large reserves of high-calcium limestone have been test drilled in the Camden and Pipe Creek Jr reefs. The dolomitic parts of the reefs are mostly far-flank beds that are gradational with dolomitic interreef beds, but a test core drilled near the center of the Camden reef showed fine-grained gray dolomite in the upper part of the core. Some dolomitic limestone has also been drilled in parts of the flank rock of the Pipe Creek Jr reef. The dolomitization has been partly related to the original porosity of the dolomitized beds (1, 13).

Of the 17 known reefs in Indiana containing limestone, only the Camden and Pipe Creek Jr reefs have large commercial reserves of high-calcium limestone. The other reefs are a few hundred feet to less than a quarter of a mile in diameter at the bedrock surface and commonly less than 100 feet thick. Although these reefs might be profitably exploited with mobile crushing plants, reserves of any individual reef would probably not be sufficient for a permanent processing plant. Besides, many of the smaller reefs contain some gray to tan dolomite and significant amounts of impurities, especially on the weathered outcrops of the reefs.

Ault and Carr (2) presented results of chemical analyses of limestone from 15 reefs in north-central Indiana and discussed methods of exploration in an area of known limestone reefs (Figure 6), an area that would also have the greatest potential for future sources of high-brightness limestone.

High-calcium limestone is present in several rock formations of Devonian age. These include the Jeffersonville and North Vernon Limestones in southeastern Indiana and the Traverse Formation in northern Indiana. Thick high-purity limestones have been determined to occur in numerous places in these rocks (14, 15); these rocks range from light gray to tan, but our measurements show no reflectance values that exceed 86 percent. Our data suggest that limestones of Devonian age do not have exceptional brightness and have limited commercial potential. Beneficiation might increase the brightness of Devonian limestones, but we have no data to confirm this assumption.

Dolomites and dolomitic limestones of Silurian and Devonian age range from gray to brown and are somewhat darker than the high-calcium limestones, but our tests have not included dolomitic rocks, and a comprehensive evaluation of the brightness of these rocks has yet to be made. Light-gray dolomitic rocks are found in some formations, notably the Laurel Member of the Salamonie Dolomite (Silurian) and the Louisvile Limestone (Silurian), and a very light buff high-purity dolomite from the Salamonie Dolomite has been quarried for use as filler at the Meshberger Bros. Stone Corp. Quarry near Portland, Jay County.

Weighted averages of chemical analyses for the Camden limestone reef show a great thickness of limestone suitably pure for fillers. Brightness values plotted against depth (Figure 7) indicate that substantial thicknesses of a very bright limestone also occur in parts of the reef. Values were not determined for all samples.

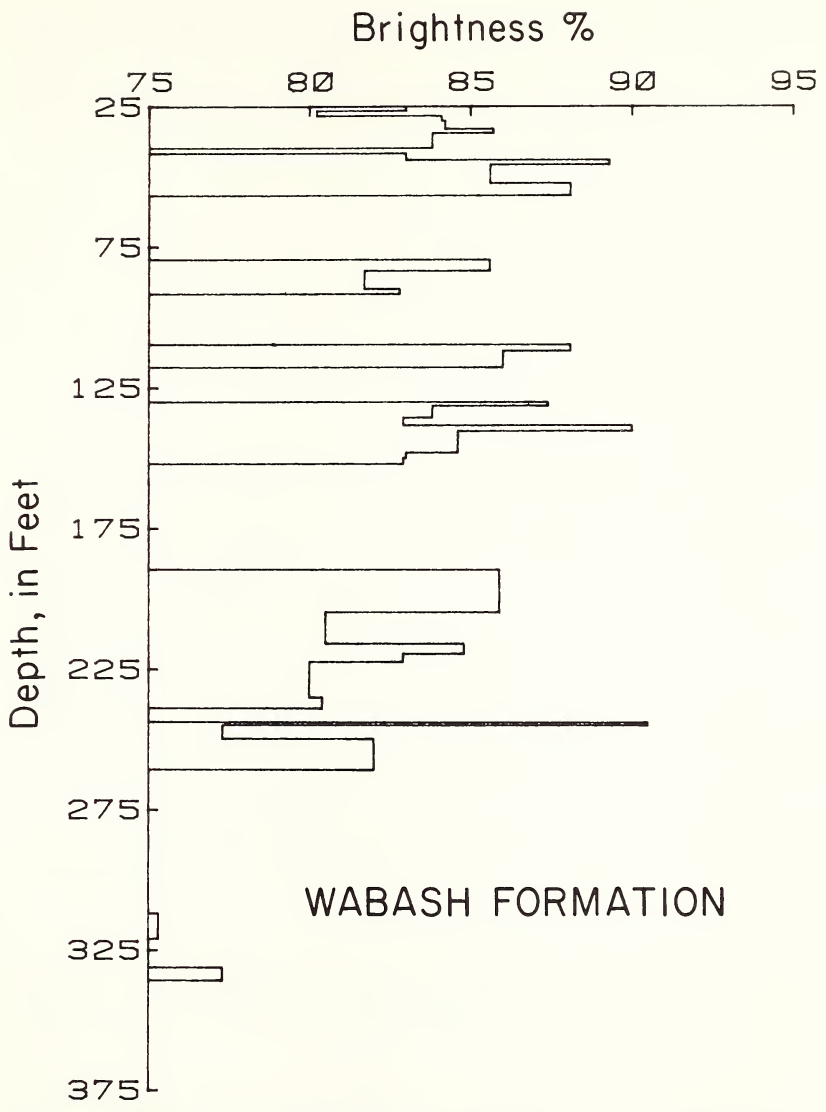

FIGURE 7. *Distribution of brightness values with depth in a limestone reef of the Wabash Formation in Carroll County.*

Limestones of Mississippian Age

Chemical analyses indicate high-calcium limestones in the Paoli, Ste. Genevieve, St. Louis, and Salem Limestones (5, 14). Samples from the Salem and St. Louis Limestones generally gave relatively low values for brightness (Figure 5). But no beneficiation was attempted on any limestones, and simple treatment might yield improved brightness results. Rocks of the Ste. Genevieve Limestone have

good potential for filler raw material with brightness values near 90 percent and an average of 81 percent reflectance. The Paoli Limestone also has some potential.

High-calcium limestone in beds more than 10 feet thick occur in the Harrodsburg, Salem, and Ste. Genevieve Limestones of Middle Mississippian age and in the Paoli, Beaver Bend, Beech Creek, and Glen Dean Limestones of Late Mississippian age. Only those in the Salem, the Ste. Genevieve, and the Paoli are thought to be extensive enough to be commercially important.

The dimension-stone facies of the Salem Limestone, which occurs in beds as much as 75 feet thick in the Bedford-Bloomington District, has consistently tested to be about 97 percent $CaCO_3$ and 1.5 percent $MgCO_3$ (14), but its gray and buff colors, due to small amounts of iron oxide and organic matter, reduce its desirability for high-brightness limestone. Brightness measurements for the Salem have never exceeded 82 percent and have averaged only 69 percent, which suggests that the Salem has limited commercial importance. We have not attempted beneficiation techniques to increase brightness.

The Paoli and Ste. Genevieve Limestones, which crop out along a belt from central Putnam County to Crawford and Harrison Counties along the Ohio River, are grouped together because they contain similar lithologies (4). Although high-calcium limestone of several textural types is found in these formations, the oolitic limestones are the most important sources for high-brightness limestones.

Oolitic limestones comprise about 20 percent of the Paoli and the Ste. Genevieve along the outcrop belt of southern Indiana (4). They are found as beds of irregular distribution from the upper part of the Paoli to the lower part of the Ste. Genevieve. In an area near Orleans, Orange County, an oolite body was mapped and found to be about 2 miles wide and 4 miles long; its greatest thickness was about 25 feet. The geometry of oolitic limestones is generally lenticular, and where the oolitic facies becomes thinner, it is generally replaced by limestones of less purity In places the oolitic beds are stacked one upon another.

The oolitic limestones consist of fine- to medium-grained ooids that have been cemented with sparry calcite. In thicker beds, say those greater than 8 feet thick, the grains in the upper and lower parts are generally more tightly cemented than are those in the middle. The purity of the oolitic limestones is high, averaging about 98 percent $CaCO_3$ and 1 percent $MgCO_3$.

The distribution of brightness values from a core in Orange County (Figure 8) shows relatively bright limestones for substantial thicknesses. High brightness values are especiall prevalent in the oolitic limestones between 75 and 100 feet. The whiteness of oolitic limestones can be observed in many exposures, but expecially in fresh quarry faces.

The Ste. Genevieve Limestone in Harrison County has several limestones with high brightness (Figure 9) that are not necessarily related to oolites.

Chemical Considerations

We found that brightness was only poorly, if at all, correlated with calcium carbonate (Figure 10A) or iron oxide content (Figure 10B). These figures show only data from the Camden reef, but our plots of other samples show the same trend. The lack of correlation probably indicates that impurities other than iron oxides cause the poor brightness characteristics of rocks of the Muscatatuck Group and the Salem Limestone.

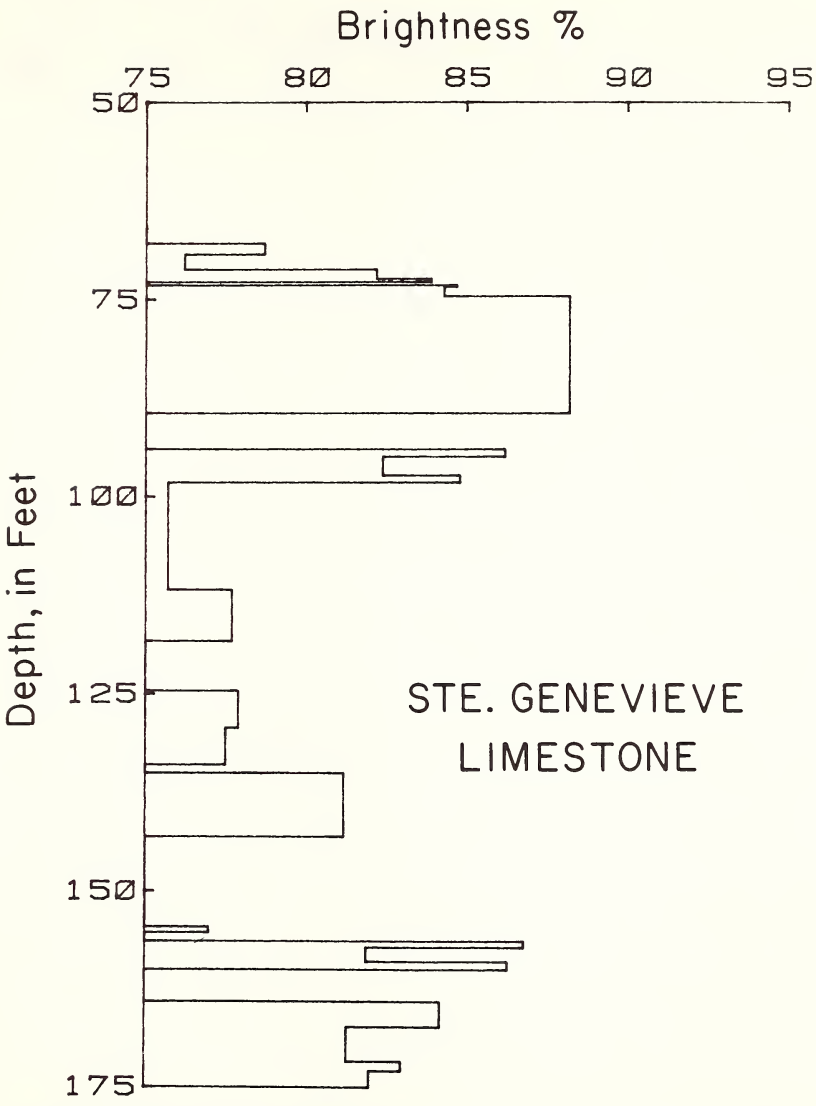

FIGURE 8. *Distribution of brightness values with depth for limestones of the Ste. Genevieve in Orange County.*

Summary

Several limestones, most notably those in the Ste. Genevieve Limestone and the Wabash Formation, have the chemical purity and the brightness values to make them potential raw materials for fillers. Sites in Carroll County in northern Indiana and in Orange County in southern Indiana contain relatively thick sections of suitable limestone and are well located to offer attractive targets for develop-

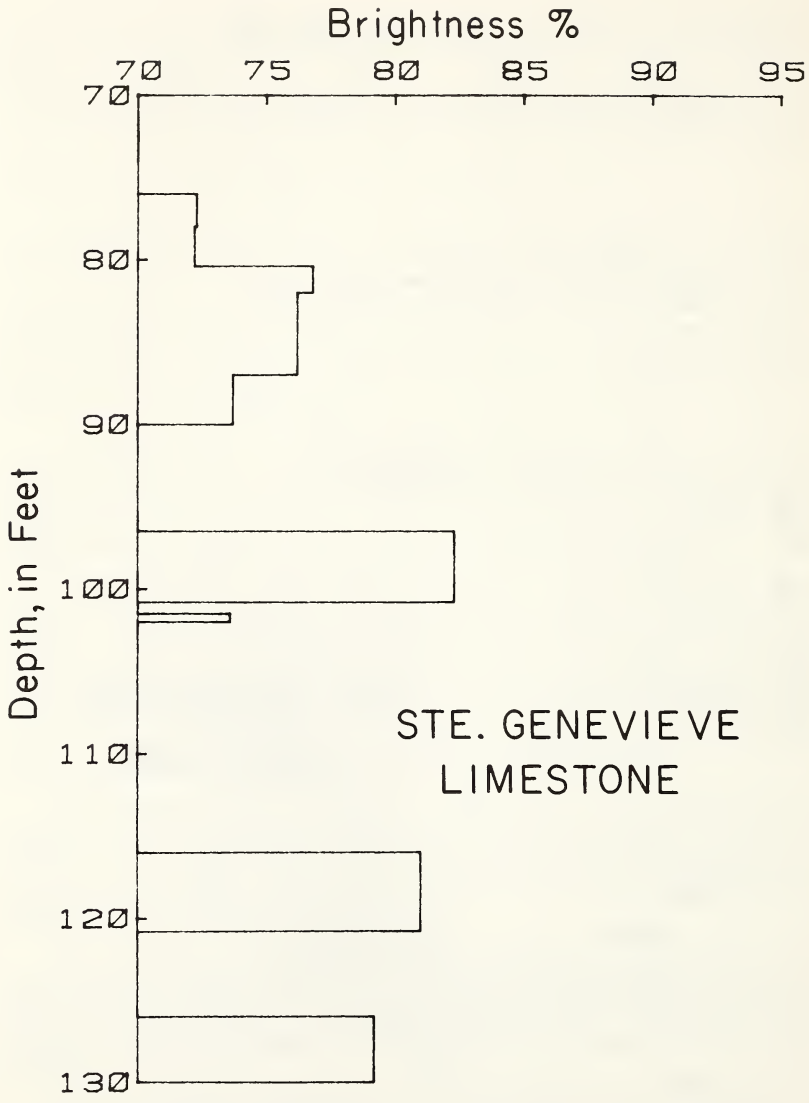

FIGURE 9. *Distribution of brightness values with depth for limestones of the Ste. Genevieve in Harrison County.*

ment. A filler-producing company recently announced that it intended to develop a large white limestone deposit at Camden in northern Indiana. This announcement may indicate that production of filler materials in Indiana is not far in the future.

Acknowledgments

We wish to thank Dr. Haydn H. Murray, Department of Geology, Indiana University, for lending equipment, numerous industry sources for giving product

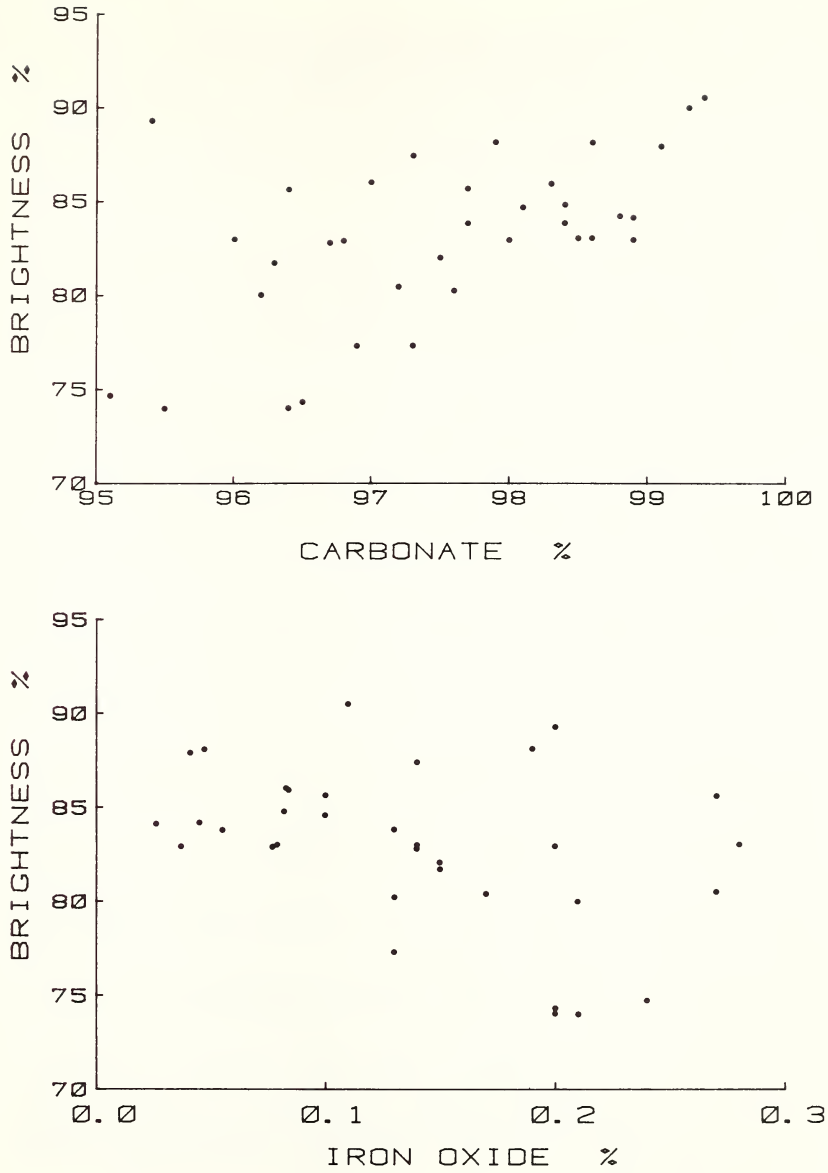

FIGURE 10. *Scatter diagrams showing distribution of brightness values with percentage of calcium carbonate (A) and iron oxide (B) for limestones in the Camden reef, Carroll County.*

information, and the Pulverized Limestone Association for providing information about test procedures.

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Uppermost St. Louis Limestone (Mississippian): the Horse Cave Member in Indiana

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Abstract

The Horse Cave Member, named for exposures at Horse Cave, Hart County, Kentucky (15), extends into southern Indiana and constitutes a distinct, mappable subdivision of St. Louis Limestone. Horse Cave strata crop out from the Ohio River to at least Owen County. Thickness of the unit typically ranges 35-50 feet.

Overlying the Horse Cave Member is the Fredonia Member, the lowest subdivision of Ste. Genevieve Limestone. The uppermost beds in the Horse Cave Member are dark-colored dolomites or dolomitic limestones which are overlain by a white, well-sorted, cross-bedded oolite, the lowest Fredonia lithology. The contact is placed between the dolomite and oolite. The Lost River Chert Bed (8) is found slightly below the dolomite and is an excellent, laterally-persistent marker. The lowest beds in the Horse Cave Member are grey biosparites which may locally be oolitic. These beds overlie a dark-colored dolomite which caps a zone of conspicuous spherical and lenticular chert. The contact is placed between the dolomite and biosparite. The base of the Horse Cave Member approximates the traditional St. Louis-Ste. Genevieve contact in Indiana. However, faunal and lithologic evidence argue that the formational boundary be raised.

Introduction

The Blue River Group (10) contains, in ascending order, St. Louis Limestone, Ste. Genevieve Limestone, and Paoli Limestone (Figure 1). These Mississippian carbonates crop out from the Ohio River into Putnam County (Figure 2), but their occurrence north of Greencastle, Putnam County, is sporadic owing to less deposition and to pre-Pennsylvanian and Pleistocene erosion (6). Aggregate, depositional thickness of the St. Louis and Ste. Genevieve varies from roughly 150 feet in Putnam County to 500 feet in Harrison and Crawford counties. Regional dip is slight and generally to the west-southwest, into the Illinois Basin. Horse Cave strata dip west 30-35 ft/mi in Harrison County (14,22), somewhat more gently than in Lawrence and more northerly counties.

Review of Literature

Because acceptance of the Horse Cave Member implies acceptance of a revised St. Louis-Ste. Genevieve contact in Kentucky and Indiana, a brief recounting of changes in nomenclature is appropriate.

Precise and consistent delineation of the St. Louis-Ste. Genevieve contact has long provoked debate and consternation among geologists working in the Illinois Basin. Fundamental reasons for the lack of harmony are three: (1) scarcity of outcrops, (2) guide fossils believed restricted to one formation which, in fact, are found in both, and (3) transitional lithologies in the interval between undoubted St. Louis and undoubted St. Genevieve. Location of the contact in Indiana commonly varies by as many as 50 feet.

Although named by Englemann (9) and Shumard (17), the St. Louis and Ste.

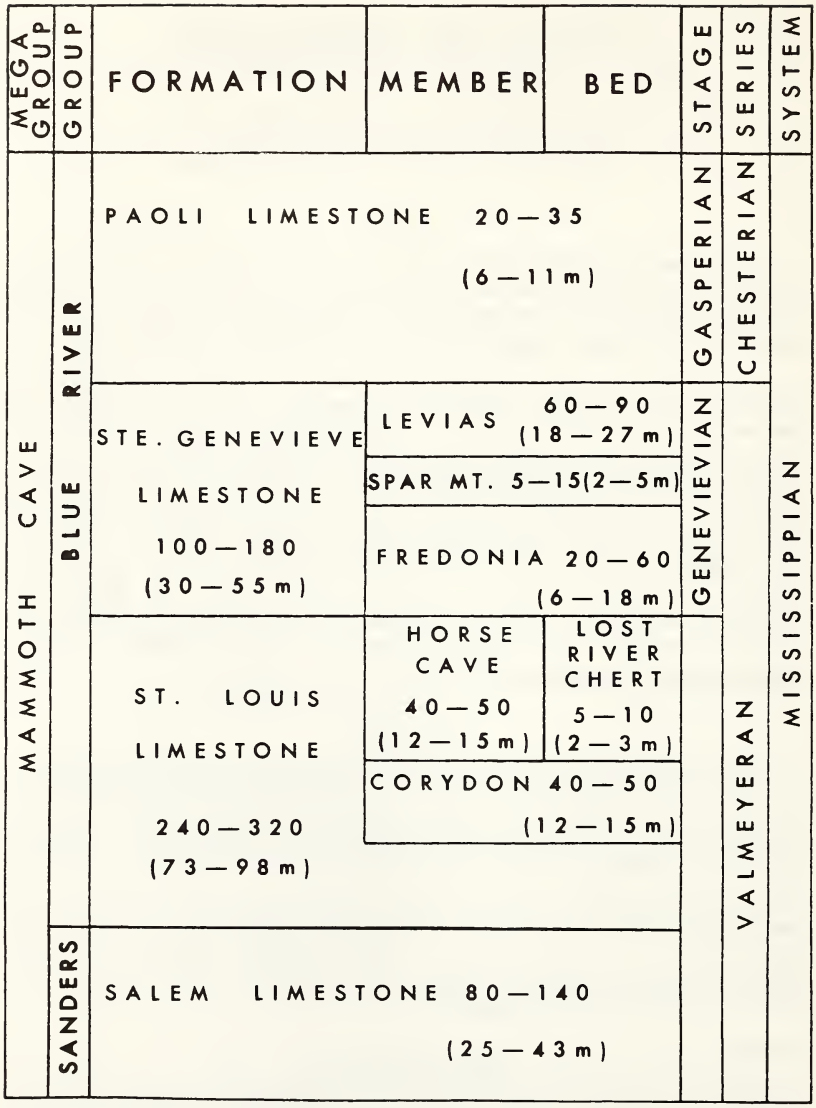

FIGURE 1. *Stratigraphic column for some of the units exposed in Harrison County, Indiana. Thicknesses in feet.*

Genevieve were first described in detail by Ulrich (19,20), who restricted the St. Louis Limestone and resurrected the term Ste. Genevieve.

In Indiana, Siebenthal (11) proposed the Mitchell Limestone for carbonates between the pseudo-oolitic facies of the Salem and, presumably, the Bethel Formation. Thus, Mitchell Limestone, as initially described, included uppermost Salem beds and the complete St. Louis-Ste. Genevieve-Paoli interval. Elrod (8) proposed

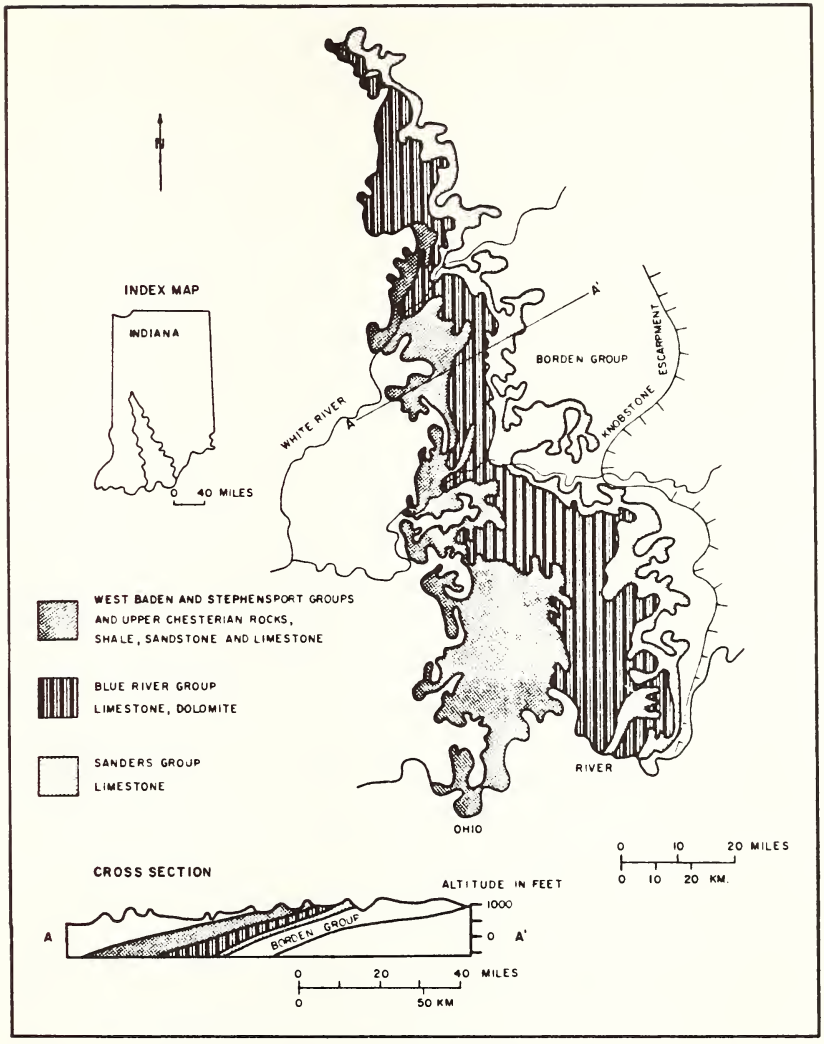

FIGURE 2. *Generalized geologic map of upper Mississippian strata in southern Indiana (after Palmer and Palmer. 1975).*

that a highly-fossiliferous chert bed, the Lost River Chert, serve as an interformational marker separating a restricted Mitchell [St. Louis and highest Salem] from Paoli [Ste. Genevieve and Paoli]; the chert was assigned to neither formation. Although Beede (4) suggested that St. Louis and Ste. Genevieve equivalents are present in Indiana, he refrained from formally recognizing them, instead retaining the nomenclature of Siebenthal. Apparently Beede (4) was unfamiliar with Elrod's proposal, for he notes that there exists a

"chert horizon, frequently very fossiliferous, which ranges from three to

> four inches to a foot or more in thickness. Much of the Mitchell carries chert, but this horizon seems to be a silicious limestone becoming chert on weathering . . . . Near this horizon, perhaps just above it, is a zone varying from an inch to several feet of oolitic limestone with quartz and other sand grains . . . . The grains are true oolite [ooliths]."

Cumings formally recognized St. Louis Limestone and Ste. Genevieve Limestone in Indiana, placing the contact at the top of Lost River Chert (7). Malott placed the contact lower, at an unconformity 10-20 feet below Lost River Chert; the presence of oolitic beds and of *Platycrinites penicillus*, as well as the unconformity, were cited as reasons for the change (12, 1). McGrain put the boundary below the "lowest oolitic bed," 15-22 feet below Lost River Chert in Harrison County (14). McGrain's Figure 5 depicts the contact at the top of a dolomite which is underlain by cherty limestone. Malott (13) subscribed to McGrain's findings, stating that the boundary "may be clearly identified at the top of beds containing nodular and ball chert and more or less abundant silicified *Lithostrotion proliferum* . . . about 20 feet below the Lost River chert in the lower Ste. Genevieve limestone."

Study of conodont assemblage zones led Rexroad and Collinson (16) to place the St. Louis-Ste. Genevieve boundary well above that established by Malott; at Springville they drew the contact at the base of the Spar Mountain Member.

Pohl found the Ste. Genevieve guide fossils *Platycrinites penicillus* and *Pugnoides ottumwa* 65 feet below Lost River Chert in the Mammoth Cave region (15). This occurrence strongly suggests that the above taxa extend well into strata of indisputable St. Louis lithologic and paleontologic character. Pohl proposed a new subdivision of St. Louis Limestone, the Horse Cave Member, which embraces the transitional lithologies between the lowest oolite in the Ste. Genevieve and the highest ball chert in the St. Louis. The upper limit of the Horse Cave Member "marks the viable extinction, although perhaps not the final occurrence in this part of the world, of the foraminifer genus *Eoendothyranopsis* Reitlinger 1966 and the dasyclad algal genus *Koninckopora* Lee 1912 emend. Wood 1942."

St. Louis Limestone

The St. Louis Limestone comprises, in descending order, three lithostratigraphic units: the Horse Cave Member, Corydon Member (22), and lower St. Louis. Lithologies of the upper two units represent a high-energy, open-shelf depositional environment, whereas those in the lower St. Louis represent a low-energy, areally-restricted environment. Dolomites, shales, evaporites, and sparsely-fossiliferous limestones characterize the lower St. Louis.

The Corydon Member is composed of thin-bedded biosparite and biosparrudite which are associated with massive dolomites and abundant chert. Two forms of chert predominate: lenticular and spherical. Lenticular chert is 1/2-2 inches thick, parallel to bedding, and sometimes fossiliferous. Spherical to nodular, concentrically-banded chert balls having diameters 1-2 inches lie closely spaced, usually subparallel to bedding. Corallites of *Lithostrotion proliferum* are found in many of these semi-bedded chert balls. Overlying the zone of plentiful spherical and lenticular chert are several feet of dolomite and dolomitic limestone which are relatively chert-free; these are the highest beds in the unit.

The distinctive and copious cherts are a reliable guide to the Corydon Member in Indiana and are found along outcrop from central Putnam County to the Ohio River. The massive lithostrotionid corals, which are guides to the St. Louis, terminate in the Corydon Member.

Horse Cave Member

The Horse Cave Member, named for exposures in the Mammoth Cave region of Kentucky, is a well-defined unit in Indiana from the Ohio River to at least Owen County (Figure 3). Thickness ranges 20-50 feet but is characteristically 35-50 feet (Figure 4). Thickness in the Mammoth Cave area also ranges 35-50 feet.

The lower contact of the Horse Cave Member is beneath a light-colored biosparite or biopelsparite which overlies dolomite of the Corydon Member. This boundary, which is locally disconformable, is probably where Malott (12,13) and McGrain (14) placed the St. Louis-Ste. Genevieve contact. The lowest lithology in the Horse Cave Member occasionally contains ooliths, but the principal constituents are fragmented fossils which, in hand specimen, may superficially resemble ooliths. Beds in the lower portion of the unit are usually light-grey biosparites and biosparrudites rich in crinoid columnals, ooliths, bryozoans, and brachiopods. Relative proportions of these constituents appear to vary laterally in the lower beds.

FIGURE 3. *Index map of south-central Indiana. Numbers correspond to columns in Figure 4: (1) Corydon, (2) Orleans, (3) Springville, (4) Bloomington.*

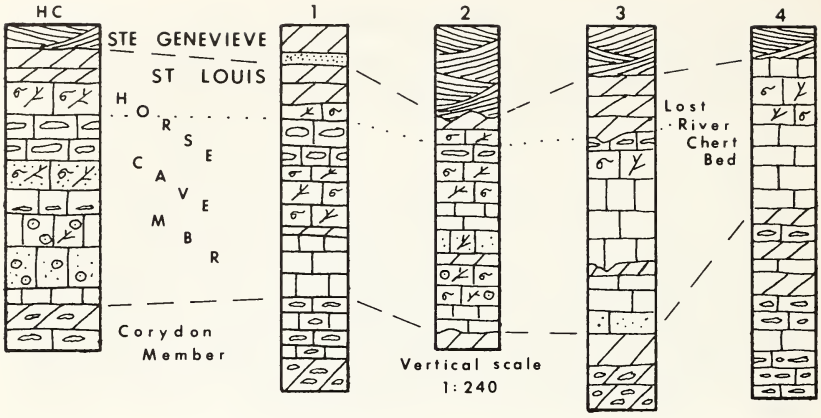

FIGURE 4. *Columnar sections showing correlation between the type section (HC) and the Indiana outcrop.*

Bryozoan beds overlain by dolomite characterize the upper part of the Horse Cave Member. The bryozoan lithology is coarse-grained, quite stylolitic, sparry, usually white, and contains a multitude of well-preserved fenestellid bryozoans, spirifer and productid brachiopods. Crinoid columnals are not abundant. Where some of the bryozoan beds have been differentially silicified, the resulting lithologic zone is called the Lost River Chert Bed (8, 18).

Lost River Chert is an areally-extensive, laterally-persistent lithologic zone of highly-fossiliferous, blocky-weathering bedded chert having medium to coarse-grained bryo-brachio biosparrudite intercalated. Fresh chert often possesses a faintly bluish cast but may also be cream or black at the same exposure. The formal bed is 2-11 feet thick in southern Indiana and is an excellent structural datum from Simpson County, Kentucky, to Springville, Lawrence County, Indiana, roughly 180 miles along regional strike. Sporadic occurrences of the chert are known farther north in Monroe, Owen, and Putnam counties.

Significant changes in microfauna take place in the upper part of the Horse Cave Member. At the type section, Pohl depicts the end of *Eoendothyranopsis* slightly below the base of Lost River Chert and the demise of *Koninckopora* coincident with the top (15). Baxter (2) finds these faunal breaks replicated at comparable lithologic horizons at Mauckport (southern Harrison County), Orleans (Figure 4, no. 2), and Springville (Figure 4, no. 3). Baxter and Brenckle (3) consider the disappearance of *Eoendothyranopsis* in the upper St. Louis one of the major extinctions among Mississippian calcareous foraminifera of the mid-continent.

The highest beds in the Horse Cave Member are dark-colored dolomites and dolomitic limestones. Ranging 2-10 feet thick, this zone is usually algal in part. Present evidence suggests that much of the dolomite is dolomitized micrite. Several feet of limestone usually intervene between the dolomite and Lost River Chert, but at some localities the limestones are absent and dolomite rests unconformably on scoured Lost River Chert. Where this situation exists, the lower 8 inches of dolomite contain rounded quartz grains and subrounded to subangular fragments of Lost River Chert commonly to one inch in greatest dimension. The chert was apparently lithified prior to being eroded; thus, its age is pre-Genevievian Val-

meyeran (Mississippian). Additional evidence supporting an early diagenetic origin is provided by Withington and Sable (21), who note that the Bethel channel-fill (Gasperian Stage, Chesterian Series) sometimes contains a breccia or conglomerate at its base which "consists of tabular to sub-rounded chert fragments 2 to 5 inches in length, most of which derived from the Lost River (?) Chert of Elrod (1899) . . . ."

Overlying the zone of dolomite is a white, fine to medium-grained, moderate to well-sorted oolite. The Horse Cave-Fredonia contact, which is sometimes disconformable, lies between the dolomite and oolite. Although the basal lithology of the Ste. Genevieve is at some localities only 1-2 feet thick, it is characteristically five or more feet thick, well-indurated, and prominently cross-bedded. Unlike the locally oolitic limestones found in the Horse Cave Member, these are true oolites (carbonate sand bodies). In Indiana, the classic oolite bodies of the Ste. Genevieve, such as Carr (5) described at Orleans, lie above the Horse Cave Member.

In lithology, thickness, and paleontology, Horse Cave strata in Indiana closely resemble those in the type area. Gradual changes in thickness and lithology do not commence until north of Lawrence County.

The thickness of the Fredonia Member, unlike that of the Horse Cave, varies considerably. In Harrison County the Fredonia is 20-60 feet thick; at Springville it is only 2-7 feet thick. Some of the variation in thickness is attributable to the local relief of oolite bodies. The particular oolite body which Carr (5) detailed at Orleans overlies the highest bed of the Horse Cave Member and underlies the Spar Mountain Member. Therefore, at Orleans, the thickness of the Fredonia Member is a function of oolite-body geometry. The oolite body has a "maximum measured thickness of 25 feet and thins irregularly toward its margins (5)."

Summary

The Horse Cave Member is a distinct, recognizable unit in southern Indiana. Lithologically, it approximates the interval between the lowest oolite in the Fredonia Member and the highest ball chert in the Corydon Member. Paleontologically, it marks the departure of *Eoendothyranopsis* and *Koninckopora* from the Mississippian.

Reference Section

The reference section for the Horse Cave Member is the Armstrong Quarry and Roadcut, near Springville, Lawrence County. The lower contact is well-exposed in the quarry floor. The upper contact may be examined in the roadcut immediately north of the quarry. An unusual aspect of the upper contact at the Armstrong Roadcut is that, although dolomite is present, the highest Horse Cave lithology is fossiliferous micrite. The apparent absence of this lithology at nearby exposures is attributed to dolomitization. The upper contact is clearly defined at the Springville Quarry (SE ¼, SE ¼, sec. 29, T.6N., R.2W.) and at a roadcut on the north side of SR 58 (E ½, sec. 31, T.6N., R.2W.), slightly west of the Armstrong Roadcut.

Armstrong Quarry and Roadcut NE ¼, SW ¼, sec. 32, T.6N., R.2W., Owensburg 7.5′ Quadrangle, Lawrence County, Indiana

Ste. Genevieve Limestone		>2.0′
Fredonia Member		2.0′
		Covered.
14.	2.0′	Covered.
		Dense, white, fine-grained oolite (oosparite).

St. Louis Limestone		>52.6′
	Horse Cave Member	40.3′
13.	3.2′	Dense, pink to cream-colored fossiliferous micrite.
12.	1.8′	Soft, porous, dark-brown dolomite having peculiar boxwork structure when weathered. Weathers to recess; interval partially covered.
11.	0.5′	Sandy sparite; 5-10% subrounded quartz grains.
		(TOP OF QUARRY)
10.	2.3′	Lost River Chert zone; highly-fossiliferous chert and white, bryo-brachio biosparrudite.
9.	5.0′	Bryozoan beds; white, thick-bedded, stylolitic bryo-brachio biosparrudite.
8.	10.8′	Light-grey, cross-bedded, stylolitic biosparite. Minor lenticular and nodular non-fossiliferous pink chert 5.3-7.5′ above base of unit.
7.	5.8′	Grey, thick-bedded, dense biosparite.
6.	1.0-1.5′	Tan dolomite.
5.	7.4-7.9′	Light-grey to white biosparite and biopelsparite.
		(QUARRY FLOOR)
4.	2.0′	Light-grey biosparite and biopelsparite; pseudo-oolitic; bryozoan debris.
	Corydon Mbr.	>12.3′
3.	5.2′	Massive tan dolomite; minor blebs of chert.
2.	2.6′	Dolomite containing mottled (pink, grey, and brown) chert at top.
1.	4.5′	Massive dolomite. Irregular and spherical chert in lower four feet; thick, non-fossiliferous semi-bedded chert in upper 6 inches.
		(Water level, March 1981)
		(QUARRY PIT)
Total measured section		54.6′

Acknowledgments

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HISTORY OF SCIENCE

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ABSTRACT

The Origin and Derivation of Insect Names and Entomological Terms. B. Elwood Montgomery, Department of Entomology, Purdue University, West Lafayette, Indiana 47907.——Information of the origin and history of insect names furnishes us evidence of the knowledge of insects possessed by ancient peoples. The names of many common insects, as ant, bee, beetle, fly, *et al.*, are much older than the English language itself. At least some of these names may be traced back through ancestral languages—Anglo-Saxon and the primitive Germanic branch languages—even to the Indo-European. Of course, these names, as most other words, have undergone changes in both form and meaning. The changes in form of words are frequent enough to justify the observation, credited to Voltaine, that "etymology is a science in which vowels do not count at all and consonants very little." The changes are, for the most part, not random but follow rather rigid linguistic "laws". Perhaps, the best known of these "laws" is the sound shifts in the Germanic languages in which p. t, and k(c) become f, th and h, respectively, known as Grimm's Law. Thus, *centipede* (borrowed or derived from Latin) and hundred-footed not only mean the same but are essentially the same word as modified from the ancient Indo-European during inheritance into Latin and English (*centum* - hundred + *pes, pedis* - foot). In addition to inheritance, names of insects may be brought into English by borrowing words from other languages or by formulation in modern English. The "Common Names of Insects and Related Organisms" of the Entomological Society of America have all been coined within very recent times. The "loan" names, acquired from other languages may undergo considerable change as they are molded into "accepted" English form by folk etymology. Thus, the Spanish *cucaracha* introduced into English as "cacarootch" by John Smith about 1600 has become cockroach.

Previous papers (1973, Great Lakes Ent., 6(4): 121-128 and 1973, Proc. Ind. Acad. Sci., 82: 235-241) on the form and types of insect names and the common names of dragonflies (Odonata) in English and Celtic contained information on the etymology of certain insect names. This paper is designed to extend these studies to include most of the names of the more common insects.

Early Years
Paul Weatherwax

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[In cleaning out Dr. Weatherwax's office after his death I came across a manuscript, an autobiography. As I read through it, however, I realized that certain parts were missing. I thought that perhaps he had never completed it but when calling his son, Charles, to inform him of my discovery, I learned that he had found the missing parts in Dr. Weatherwax's home. Because of his many contributions to science education in the state of Indiana and his interest in the Indiana Academy of Science — he was a member for 63 years,* it seems most fitting that his autobiography be published in the pages of these Proceedings. The first chapter is presented here and it is hoped that others will follow in subsequent volumes. By way of introduction I include a brief sketch of his life.

Paul Weatherwax was born near Worthington, Indiana, on April 4, 1888. He grew up on a farm and received his early education in one room schoolhouses. Following graduation from high school at Worthington in 1907, he returned to one room schoolhouses near Worthington to teach for two years. His first college courses were taken at Wabash College in the spring term of 1909 and at DePauw University in the 1910 summer session. During the years 1910 and 1911 he taught high school, first at Owensburg and then at Freedom where he served as principal as well as teacher of most of the courses. *Freedom*, he has written, was a good name for the town but *Licenses* would have been better, for he had difficulty in stimulating any interest in orderly behavior or things intellectual. He enrolled at Indiana University in the spring of 1911, but he had to return to teaching at Greencastle for a year in order to secure funds to continue his education at the university. He received the bachelor's degree in 1914, the master's in 1915, and the doctorate in 1918. In the summer of 1913 he was part of a party employed by the Indiana State Board of Health to survey pollution in Indiana streams, and thus he early became aware of problems that only more recently have become of general concern to the ecologist. From 1913 to 1915 he served as an assistant in botany at Indiana University, and in 1915 he became an instructor in botany serving in that position until 1918. Prospects for continuing at Indiana University were not bright at that time so in 1919 he accepted a position as Associate Professor at the University of Georgia. In 1921 he eagerly accepted the invitation to return to Indiana University, and he was to spend the next 37 years teaching for that university. In 1957 he joined the group from Indiana University in the United States Operations Mission in Thailand where he was primarily concerned with training teachers of biology. Although he was made Emeritus Professor in 1959, this did not bring an end to his teaching, for in 1960 he was invited to serve as a visiting professor at Franklin College where he taught for three years. In 1963 Franklin College awarded him an honorary doctorate of science. His last formal teaching was done at Hanover College in 1966; but in the remaining days of his life, his office at Indiana University was always open to students who wished to consult with him.

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*See Proc. Ind. Acad. 86: 63-65. 1977. for his many contributions to the Society.

Dr. Weatherwax's teaching career spanned 50 years, and he will be remembered foremost as a teacher, as he would want to be. He received his greatest pleasure from teaching the elementary botany course; and at a time when many professors felt that the elementary courses should be relegated to the junior faculty members, by choice he continued teaching this course until his retirement. He took delight in having children of his former students enroll in his course, as frequently happened. His interest in teaching of elementary students led to the writing of a textbook, *Plant Biology*, the title of which was changed to *Botany* in the third edition, the one that he had preferred all along. He also taught his share of advanced courses. One of the most popular of these was a seminar in the morphology of grasses, given at the request of graduate students. His intimate knowledge of the grass family combined with his teaching ability made it possible to make this most difficult family intelligible. Perhaps the course most fondly remembered by his students was the summer field trip to Florida, a course that he introduced to acquaint them with tropical botany.

As great as was his dedication to teaching, he never neglected research. Beginning his research as an undergraduate he continued with it until long after his formal retirement. His first scientific papers were published in 1914. Dr. Weatherwax was a most versatile botanist, but for his field of specialization he chose morphology, particularly the morphology of grasses, and no grass was to be of greater concern to him than was the corn plant. His doctoral dissertation was entitled *The Evolution of Maize*, and in 1923 his first book, *The Story of the Maize Plant*, appeared. As others have pointed out, it was his early interpretation of the structure of the corn plant in relation to other grasses that was to set the stage for the understanding of the origin of the corn plant. He was concerned not only with the morphology of the plant but with many other aspects as well, particularly its origin and history, which culminated in his *Indian Corn in Old America* published in 1954. His travels in connection with his research took him to the southeastern and southwestern United States and to many parts of Latin America. His studies were aided by a Waterman fellowship from 1925 to 1930 and a Guggenheim traveling fellowship in 1944. He was also a noted botanical illustrator, and he became widely recognized for the illustrations he made for C. C. Deam's *Grasses of Indiana* in 1929.

Dr. Weatherwax was a member of a number of societies, and he was particularly active in the affairs of the Botanical Society of America and the Indiana Academy of Science. He served as president of the latter society in 1941. He was secretary of the Botanical Society from 1939 to 1943 and was elected vice president both in 1944 and 1957. In 1976 he received a Certificate of Merit from the society in recognition of his distinguished achievement and contributions to the advancement of botanical science.

Paul Weatherwax died on October 18, 1976 in Bloomington.

Charles B. Heiser, Indiana University]

PREFACE

Anyone who has taken an active part in the stirring events of the past fourscore years and more ought to have made some observations and accumulated some memories worth recording for whatever use the future may make of them. It is a common human failing not to recognize history when it is being made. No time is so little understood and appreciated as the present and no place so little ap-

preciated as the place where we now live. Only from the perspective of time and space do we properly value the here and the now.

In our attempts to reconstruct pictures of the past, especially those of local interest, every fragment of information recorded by an observer on the spot is precious. Letters, diaries, family records, obituaries, epitaphs, and newspaper items all make their contributions. Even when some of these prove to be erroneous, they all have their unique importance when properly evaluated.

It is, then, with a feeling of this implied responsibility—and at the strong insistence of relatives and friends—that I undertake the task of placing on record some of the things that I remember, for whatever use posterity may make of them. If some of my pioneer ancestors in southern Indiana had done as much, their records would have been of inestimable value today.

If we may disregard a brief attempt in my high school days, I have never kept what might be called a diary. In that one venture I decided to write in Latin, to make use of an embryonic accomplishment and to protect myself from anyone who might be looking over my shoulder; but I soon found the effort too great to make the project interesting and my limited knowledge of the idiom of that language a serious handicap. Fortunately, no fragment of that effort has been preserved.

In later years, when I was privileged to travel extensively in the United States and some other countries in a professional capacity, I did keep notes on my observations—some of them in no way connected with my research. These notes have been preserved and will be used. Copies of an extensive correspondence will provide further on-site data. But the main body of what I shall write will come from unrecorded memories, and I am fully aware of the fickle nature of memory. One comforting thought makes compensation for that defect. It is the time-honored maxim that memory of events of long ago is usually more clear than that of what happened yesterday.

I

My earliest recollections go back to the time when I was between three and four years old. We then lived about two miles northwest of Worthington on what was commonly spoken of as the Phegley place. I have no idea who the Phegleys were, how we happened to be living there, or even whether I have spelled the name correctly. Although this was more than 80 years ago, a few incidents still stand out more vividly than some events of only a few months ago.

My birthplace was a short distance east of there at what was known as the Andrews place. This location has been occupied since then by different families, especially the John Stahl family for several years.

A boy some six or seven years old lived nearby, probably one of the Loffland boys sometimes came over to play with me. I found him interesting because he introduced me to some new experiences. I recall his showing me how to model animals and other objects from clay, and I remember that there was one small spot in the yard where the clay was especially good for our purpose. This was geology lesson No. 1. Near the house there was a small grove of sassafras trees, some of them bearing fruits, and he showed me how to break away the drupe and eat the fleshy, red, spicy-flavored pedicel. This was botany lesson No. 1. During that summer (1891) a group of Gypsies camped for a few weeks along the creek near our house, and we visited their camp on one or more occasions. I remember their gaily colored tents and horse-drawn vehicles and sensed to a degree the vast difference between their way of living and ours.

While we lived there I had an accident, a part of the result of which is still with me. Running from one room to another one day I fell and struck my forehead against the sharp corner of the door casing, or possibly against a broken hinge. The ugly cut over my right eye healed in due time, without the aid of a doctor, but the injury must have been more than skin deep for there is still a knot there on my skull.

One more thing I remember vividly from those days. I ate my meals from a small plate which was decorated around the edge with the capital letters of the alphabet. I had some idea of how these letters went together to make words on the printed page, and I felt a strong desire to learn to read. Years later Mother used to tell how they had difficulty in getting me to move along on the sidewalks in town because I was always stopping to spell out the signs on the stores.

In the spring of 1892 we moved to a farm owed by Mother's Uncle Frank Maxwell, located along the Evansville and Terre Haute railroad and the towpath of the old Wabash and Erie canal, about two miles south of Worthington. By some mutal but unwritten agreement, March 1 was moving day, on which the tenant farmers of a neighborhood played a game of musical chairs and moved to their new locations. That year, as usual, March 1 was a raw, chilly day, and we found most welcome the fire left burning in the fireplace by the previous tenants.

The Maxwell family had moved to Iowa some time before that but were now planning to come back to Indiana. As the first step toward that move the son John came back to Indiana that spring to begin farm operations. He took his meals with us, but if I remember correctly, he slept in the barn. He was a rough, irresponsible youngster, and he found much to criticize in my deportment. I have few pleasant memories of my relations with him during that spring and summer. In spite of his unpleasant manner he later became some sort of preacher.

Another member of the Maxwell family, Uncle Frank's sister, also lived with us a part of that year. I don't know what her actual name was, but we always knew her as Aunt Setty. She was one of those peculiar half-wits, decidedly off the beam in some ways, but very kind and as sharp as a tack in many ways. I am not sure just how we managed to accommodate both of these visitors in a house which, as I remember it, had only two rooms.

Another trivial incident was worth recording. Among the things that John Maxwell had brought with him was a peck or so of navy beans which had been grown in Iowa, and to sister Winifred and me was often assigned the task of "looking" the beans in preparation for cooking them. That is, we would pour a small number of beans from hand to hand and pick out damaged ones or bits of foreign material. The principal adulterant consisted of bits of black soil, and I recall with what interest I accumulated these little clods of "Iowa dirt" as something special. They seemed to be a symbol of some far-away place which appealed to my imagination. Possibly they were symbolic precursors of the wanderlust that I was to experience in later years.

In 1892 the country was in the midst of one of the periodic economic depressions, and there was a general complaint of hard times. One characteristic aspect of this condition was the appearance of large numbers of hoboes, tramps we called them, who roamed about the country begging for a living. Many of them traveled by railroad, bumming an occasional ride on a freight train, but hitting the ties most of the time. Since we lived near the railroad we had our share of such visitors. There was a common belief that they had a system of marking gates or fences with symbols informing other members of the fraternity as to what sort of welcome they

would receive at various houses. I don't know how they had us labeled, and we were not particularly generous toward them, but we had our share of such guests. Most of them were simple-minded, harmless fellows, but enough tales were in circulation about the evil doings of some of them when they found the welcome mat upside down to engender a word of warning us about dealing with them. We youngsters had a feeling that a tramp would get is if we didn't watch out.

Dad sometimes told in later years of taking me squirrel hunting while we lived there. But I found something far more interesting than squirrels in the form of some tall weeds with enlarged knots in their stems. I do not remember whether we got any squirrels, but I did come home with an armful of what I later learned were goldenrod stems bearing insect galls. This was another botany lesson, even if I did not understand it.

Another fascinating lesson in the same science was provided by a moss rose bush which grew at one end of the house. I found the fuzzy twigs and flower buds most interesting. Also, under this rose bush there was a small patch of moss, some of the plants of which were adorned with what I later learned were sporophytes. At the time I had no knowledge of the life histories of such plants, but I did have some vague hunch that these ornamentations were to the moss something equivalent to the flowers of other plants.

Since the Maxwells were to return to Indiana and the farm would no longer be available, Dad had arranged during the summer to rent another farm about a mile farther south. He had stored hay there and in early fall had sown a field of winter barley. But, for some reason that I never knew, the deal folded up in the late fall, and we had no place to go at moving time the following spring. What to do was the big question. As a part of the answer, Grandfather Newsom deeded to Mother 59 acres of the old homestead about three and half miles north of Worthington, There was no house there, and although the beginning of winter was near, Dad and Mother decided to build one. There had apparently been a cash settlement of some kind in connection with the cancellation of the rental arrangement, since otherwise they would have had no resources for building.

During most of the winter Dad drove back and forth in the wagon each day to help in the construction. Uncle Leonard did most of the carpenter work.

At moving time in the spring the house was not yet finished, but the work was far enough along for us to move in. Mother, Winifred, Mary, and I went along with the last load of our possessions, including a coop of chickens. This was in the spring of 1893, and this house was to be our home for the next 35 years.

II

Our move to the new house on the farm north of Worthington in the spring of 1893 marked the end of our annual migrations as a part of the tenant farmer system. In this more stable environment we children spent our formative years as we grew up and, in time, left home to strike out on our own.

The farm was a part of a tract of land which my great grandfather James Newsom had acquired when the family moved to Indiana from Stokes County, North Carolina, in the early 1800's. The country was then still sparsely settled and undeveloped. A family tradition, which I heard repeated many times, told of their having seen a bear eating the offal left from butchering some time after their home was established there.

The house occuped by the Newsom family at that early date was about half a mile west of where our new home was established nearly a century later. It had also been the first home of Dad and Mother after Grandfather Newsom's family moved to the site nearer Worthington, and Winifred was born there. The old house had disappeared before I knew the locality, but the spot was marked by a few rose bushes and some plum trees. Two old barns also remained there for many years.

At the south edge of our farm was a site once occupied by the Harvey family, who were in some way related to the Newsoms. All that was left to mark the spot when we moved there was an old well and the remains of an orchard. Some of the trees were still in good condition, and in the fall of our first year there we harvested several bushels of good apples. I recall my sense of satisfaction that we had apples from our very own trees. Before that we had had apples only through the generosity of neighbors.

Only about half of our 59 acres was suitable for cultivation. An open woodland of mostly sugar maple trees occupied about ten acres, and for four or five years we tapped the trees and made maple syrup in early spring. Much of the land was rough and so worn out by cultivation and erosion that it was suitable only for pasture. Two or three springs supplied plenty of water for livestock.

In the neighborhood there was an acrimonious controversy about the merits of commercial fertilizers, and those who opposed them stuck pretty close to a rotation of corn, oats, and clover, or a mixture of clover and timothy. Dad leaned toward the conservative side and rarely used commercial fertilizer. This option was prompted by the lack of ready cash as much as anything. From the meager supply of farm literature that we had, and some school subjects, I learned of the increasing use of soy beans as a sure crop and soil builder, but I never succeeded in persuading him to try them even on a small scale. I think the cash outlay required for seed was as important in determining his attitude as was his aversion to a gamble with a new crop. For several years he rented, as a share cropper, about 10 or 12 acres along Eel River, which belonged to Grandfather Newsom, but in about one year in every three or four there was a crop failure because of spring or summer floods. The rental of a small tract of the Yancey farm, along Lick Creek, for a few seasons was subject to the same hazard, but on some occasions when the corn crop was damaged or destroyed by summer floods, a part of the investment was salvaged by a bumper crop of fall turnips. As one by-product of these lowland ventures in farming, I became proficient in fishing in the streams.

In 1893 there were not many improved roads anywhere, and the one on which our house was located was only a mud trail, dusty in summer and almost impassable in winter. But relief of a sort came when this road was included in an extensive project of gravel road building near the end of the century.

Architecturally the new house would not have taken any prizes, but it was typical of the times and better than anything we had had before that. It was constructed on apparently the only plan that Uncle Leonard had for building houses, and the work was done without benefit of blueprints or even written specifications. The house consisted of only three rooms — two square ones in front, which were used as a living room and bedroom — and, at the rear, a long room extending the full width of the building. This room served as kitchen and dining room, and one end of it as my bedroom. Years later it was divided into two rooms, and another room and a porch were added at the front.

No houses in the country, and only a few in towns the size of Worthington, had any sort of plumbing. At first our limited water supply came from a cistern filled in

the winter with rain water from the roof of the house. A well near the barn supplied water for the livestock, and later a well was dug near the nouse; but the water was so charged with minerals that it had only limited use. Bathing facilities were almost nil, and the other functions of a bathroom were provided by a little outhouse at some compromise distance from the back door. In fact, there was a feeling on the part of many in those days that the outhouse was much more sanitary—even more civilized—than the indoor facility with all its comfort and convenience.

At the back of the house we had a little building, one room of which served as a smokehouse for curing meat in winter and another which was used as a summer kitchen. The latter was more open and airy, and a bit cooler, than the indoor kitchen in summer. One serious defect in the system was the lack of adequate protection from flies. The house was screened, but there was no such provision for the summer kitchen; and the nearness of breeding places produced swarms of flies in summer. Sprays of various kinds and sticky fly paper were used with some success, but no attention was given to eliminating the breeding places although the life history of the insect was pretty well known.

The house was heated with stoves. In the spring the heating stove in the living room was taken down and stored in a closet, and the kitchen stove was moved to the summer kitchen; and in the fall this process was reversed. Just when to make these moves was always a matter of grave consideration, and I recall the shivering discomfort that I often experienced when the spring move was made too early, or even on chilly days in summer. In time we acquired a second cookstove, which was left permanently in the summer kitchen, and the one in the house provided a degree of relief for any unpleasantly cool days in summer.

Electricity as a household convenience was still in its infancy in the early years of the twentieth century, and rural electrification was still in a future of which no one even dreamed. Our only source of light was kerosene lamps—coal oil lights as they were more commonly known. Even during my high school days all my home work was done at the kitchen table by the light of one of these lamps. A well kept kerosene lamp was, however, not the grimy, smoky gadget that is often mentioned in modern times. With a clean chimney and a properly shaped wick it could provide a good light.

In those days no farm home had anything approaching modern refrigeration. A very few had ice houses in which ice harvested from ponds or streams in winter was packed in sawdust and stored for use in simple ice boxes in summer. We did not even have that facility. Our house had no cellar, but we improvised a suitable substitute. A pit dug in the back yard, walled with stone and covered over with heavy lumber and a layer of soil, provided a place where eggs, dairy products, and cooked foods could be kept cool and preserved for a few days. For somewhat cooler storage, food was sometimes places in a suitable container and suspended in the well, just above the water level. In spite of these primitive makeshifts, there were remarkably few cases of illness which could be attributed to food poisoning.

Since trips to town were inconvenient and time-consuming, they were usually limited to Friday or Saturday of each week. On these occasions the butter, eggs, or other farm products were sold, and the next week's supply of staple groceries was lain in. If, through oversight, some needed items were not included, we simply did without until the next week. On these weekly trips to town the mail was picked up at the post office. Daily rural mail delivery came with better roads in the early 1900's.

Relief from this weekly schedule of shopping was sometimes provided by

huckster wagons which toured the country roads as an adjunct to the services of some of the better general stores. These agencies did amazingly well in supplying staple groceries, dry goods, kitchen utensils, etc., and often took orders for delivery the following week of items which they did not regularly carry in stock. They usually had provisions for taking butter, eggs, and even live chickens in exchange for their wares.

In the early years of our life on the farm a special type of huckster often made weekly deliveries of kerosene for lamps and stoves. He was commonly known as Coal Oil Johnny. He also sometimes made deliveries of gasoline for use in gasoline stoves which were sometimes used for cooking in summer. The price of gasoline was usually about ten cents per gallon since it was a comparatively useless by-product of kerosene refining. The advent of thirsty automobiles ultimately put an end to this fuel bargain.

Judged by today's standards we were scarcely above the poverty level. We were well acquainted with the simple philosophy of "Make it do; use it up; wear it out." Several families in the neighborhood were much less affluent, and a few were better off economically. But very few of either group had children who graduated from high school or attended college.

Our clothing was selected for service rather than for style, but we were always neat, clean, and presentable. There was no stigma attached to wearing hand-me-downs, and when a garment had reached the end of its usefulness, it was cut into long, narrow strips, and these were sewed together and sent to the neighborhood weavers to be made into carpet.

Most of our food was produced on the farm, and under conditions which would meet the approval of the most evangelistic "organic" food faddists of today. This was simply the most convenient and least expensive way of securing food. Fruits and vegetables were canned or dried for winter use. Gallons of sauerkraut, prepared in the fall, provided an important ingredient in a balanced diet, although we had never heard of vitamins. Corn was made into lye hominy or taken to the mill and ground into meal, with the miller taking a toll of about one tenth of the meal. Our meat was mostly pork or chicken, with an occasional supplement of mutton. Since there was no efficient refrigeration, fresh meat could not be kept very long except in winter. Butchering of hogs was delayed until early winter, and most of the pork was heavily salted and smoked for preservation. Some of it was made into sausage and smoked or fried and covered with melted lard for preservation.

Eggs were used sparingly because they could readily be converted into cash for purchasing flour, sugar, and other essentials which could not be produced on the farm. The same was true of chickens, although we did use them as an important supplement of our meat supply.

Milk products were an important item of food, but since most farms had only one cow, there were occasional periods when the milk supply failed. This gave rise to a system of give-and-take among neighbors as occasion demanded. My taboo of milk and milk products placed me at a disadvantage, but my natural appetite guided me to a rather well balanced diet, and I have become a living proof that milk is not an essential ingredient of nutrition for adults.

Sorghum molasses, used as a substitute for refined sugar in many ways, had the advantage of being produced without any cash outlay. We grew the cane and took it to the local cane mill where the juice was expressed and boiled down to syrup, the mill owner retaining a part of the product as toll.

One of the greatest disadvantages of our limited economic status was the scarcity of good, interesting reading material. Every home had a family Bible, which no one ever read, and there were a few other semi-religious or moralistic books, such as The Royal Path of Life, which had been peddled around the country neighborhoods by itinerant book agents. We took the local Worthington Times and for a time the St. Louis Globe Democrat (which was, incidentally, a staunch supporter of the Republican party), and the newly established Indianapolis Star as soon as we had daily rural mail delivery. We also had a few books, mostly received as Christmas presents, which played up Mother Goose literature and a few other childhood classics. An occasional magazine which we were able to pick up somewhere was a great treat. Our school readers were almost worn out with repeated use. Their contents ran largely to patriotic or moralistic stories of the McGuffey genre.

This dearth of good reading material was sometimes relieved for us in a special way. Since the country school building was closed during the summer, it was thought best to remove the small collection of books to prevent vandalism, and we became their custodians for a few summers. This gave us an opportunity to peruse leisurely many books which we did not have time to read when school was in session. One summer we were especially fortunate. One school in the township was being closed permanently, and we were given charge of its library as well as our own. This incident provided for me an introduction to some of the early works of Harold Bell Wright, the Sherlock Holmes stories of A. Conan Doyle, and, in later years, some of the early Limberlost stories of Jean Stratton Porter.

Mother was an avid reader of a current type of light romantic fiction exemplified by the works of one Mary J. Holmes. Several women in the neighborhood had a loosely organized exchange system in which these books, usually paperbacks, were passed around until they were almost worn out. I do not recall that we children were ever forbidden to delve into this literature as we saw the books lying around, nor do I remember that we ever had any interest in it. Some of our neighbors were very much opposed to this kind of literature. Any of the stories which involved an element of suspense were supposed to be conducive to the development of nervous ailments; and, although the stories were admittedly true to life, they were frowned upon because they were not literally true.

Many years later, when Dr. A. L. Kohlmeier and I were discussing some of the folk customs of the neighborhoods in which we grew up, he told me that in Dubois County there was this same objection to fiction of any sort simply because it was "not so." I have sometimes thought that the reading ability of some was so low that this was the main basis for their objections. They found reading so laborious that the effort should be spent only on factual material, and they never read much of anything.

Although I was handicapped for any heavy farm work requiring much walking, I was kept busy with care of the yard and garden, making repairs on buildings and fences, pruning fruit trees, keeping farm machinery in working order, and other such chores. I was also able to pick up a little money by doing similar work for some of the neighbors.

I worked for Mother's cousin A. N. (Newt) Newsom during the hay-making season for three or four summers. He had a large acreage of timothy meadow, the hay from which was much in demand for horse feed. I mowed and raked hay as fast as he and his other helpers could finish the process. For this I usually received

about a dollar to a dollar and a half per day, but this provided enough for my books and other school expenses.

About 1901 or 1902 Allen Gaskill bought what was left of the old Newsom farm and moved to the house just south of us where the family of Will Newsom (Mother's brother) had once lived, and I worked for him off and on for a few summers. Gaskill was devout Methodist, guided in his farm activities by the Bible and a code based on the phases of the moon and the signs of the zodiac. For example: beans planted at one time of the moon would provide a crop which all matured at one time—obviously advantageous if you wanted to produce dry beans. But if the same variety of beans were planted during another phase of the moon, they would flower and produce beans over a longer period, this being desirable if the produce were to be used as green beans. I expressed some skepticism about this theory and suggested that we make some experimental plantings to test it. His simple answer was that it was not necessary to make such an experiment because he *knew* the facts of the case. I never could get him to disclose the source of such information.

With another of his rules of thumb the case was a bit different. When we planted potatoes he directed that they be cut into pieces with one good eye on each piece, and then two pieces droped in each hill. I asked why we could not cut the tubers into larger pieces, with two eyes on each piece, and then drop just one piece in each place. His answer was that if each piece had two eyes only one of them would make a vigorous plant. Being skeptical, I waited until he was not watching and made an experimental planting. To my surprise it turned out that he was right. I had no explanation for what I had learned, for I had never heard of the inhibiting effects that one part of a plant could have on another; but forty years later I was having my students in elementary botany make the same experiement.

From the time that I was about ten or twelve years old I had a small garden of my own. Some of the neighbors were puzzled as to why I did not concentrate my efforts on the family garden instead of wasting my time on growing a great variety of plants without regard for their usefulness, even some regarded as weeds. I had no explanation of my impractical interests, but years later they paid good dividends in connection with my work in botany.

In those days there was generally a strong feeling that as farm children grew up they should remain at home or at least nearby. Back of this there was often the selfish motive that their help was needed about the house or on the farm; but there was also the idea that the wide world was a wicked place and home was best. Enough evidence in support of this idea was provided by an occasional prodigal who had left home only to come slinking back for the barbecue of the fatted calf on finding the independence of the wide world less attractive than he had expected. Apparently little thought was given to what the result would be if this principle were carried out to its full extent, nor was much distinction made between a mere search for excitement and some more stable hunger, such as finding a job or continuing one's education, as the motive for leaving home.

Mother especially held this erroneous view, and many tears were shed when Winifred, on a visit with the Hartley family in Indianapolis, reported that she had landed a job and was planning to take a business course. As the years went by, the rest of us were able to soften the blow a bit by leaving home less abruptly. And all of us made the exodus stick and were able in later years to send financial help back home.

In the early winter of 1928-9 Dad had the misfortune of being thrown off a wagon load of corn fodder by a sudden gust of wind and suffering a broken leg.

When, after several weeks in the hospital at Linton, he had recovered to the point where he could hobble around with the help of a cane, and it became evident that his days as an active farmer were over, they sold the farm and moved to town where life would be a bit easier because of the availability of electricity and running water in the house. This move was made in March of 1929, but Mother did not get to enjoy the change in living conditions. She died near the middle of the following May. For years she had suffered from a weakened heart, complicated by hyperthyroidism, which had been partly corrected by surgery in 1920.

With various housekeeping arrangements Dad lived there to the end of his days in the late summer of 1947. But he remained active to the end. When he was past the ninetieth milestone, he was laid up for a time by a fall from an apple tree which he was pruning for a neighbor.

MICROBIOLOGY AND MOLECULAR BIOLOGY

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ABSTRACTS

S-Adenosylmethionine as a Biochemical Correlate in the Dimorphism of Mucor racemosus. Roberto Garcia, Department of Biology, Ball State University, Muncie, Indiana 47306.——Previous studies, with this dimorphic fungus, have shown that the intracellular concentration of S-Adenosylmethionine (SAM) increases approximately threefold during the aerobic or anaerobic conversion of yeasts to hyphae. The data also suggested that the increase might be a morphological correlate since it closely paralleled the time course of yeast-hyphae morphogenesis. The present report deals with an extension of those studies, utilizing a morphological mutant (COY) which requires high levels of methionine to undergo the shift in vegetative cell type and cycloleucine which is an inhibitor of the enzyme responsibile for the synthesis of SAM, to further examine the role of SAM in morphogenesis. When the COY mutant is grown in the presence of high levels of methionine it can undergo the normal shift in vegetative cell type displayed by the wild type. The magnitude and time course of the increase in intracellular SAM is similar to that seen in the wild type. However, if the mutant is grown in the absence of methionine it fails to undergo the shift in cell type. An examination of intracellular SAM revealed that the mutant experienced a tenfold decrease in this metabolite immediately after the shift to an aerobic environment which was used to induce the morphological change. In experiments with cycloleucine, an inhibitor of SAM Synthease activity, the morphological transition of the wild type was inhibited and the intracellular concentration of SAM dramatically decreased. This data coupled with that obtained from previous studies further strengthens the notion that the reported increase in SAM, observed during the conversion of yeasts to hyphae, is necessary for morphogensis. An examination of the specific activity of SAM Synthetase (in wild type *Mucor racemosus* and COY), under the experimental conditions previously described, was also part of these studies.

The Effect of Different Membrane Vesicle Preparation Techniques on Membrane Bound Enzymes of ***Paracoccus denitrificans.*** Daniel P. Kellar, William W. Baldwin and W. Marshall Anderson, Indiana University School of Medicine, Northwest Center for Medical Education, Gary, Indiana 46408.——*Paracoccus denitrificans* is the organism of choice in studing energy linked reactions in bacteria because of the similarities between the electron transport chain of *P. denitrificans* and mammalian mitochondria. Bacterial membrane vesicles that contain the enzymes of these energy linked reactions can be prepared by numerous methods. We studied several of these methods for vesicle preparation. Membrane vesicles were prepared in four ways. The organisms were converted into vesicles by means of sonic disruption, physical disruption by glass beads, enzymatic disruption using lysozyme and by treatment with a french pressure cell. Each preparation

exhibited some degree of inside-out orientation with respect to the physical make up of the vesicles. Transhydrogenase, NADH-oxidase, ATPase, and succinate dehydrogenase enzymatic activities were determined and were found to be dependent upon the manner in which these vesicles had been prepared. The results indicate that the final use to be made of the vesicles should indicate the method of preparation.

The Effect of the Host Genome on the Precise Excision of Tn*10*. DAVID P. KREPS, Department of Biology, Manchester College, North Manchester, Indiana 46962.——The effects of various mutations involving aspects of DNA repair, replication, and recombination upon the frequency of precise excision of the transposable genetic element Tn*10* were studied. *Escherichia coli* K-12 strains with a common *hisG*::Tn*10* insertion were constructed from *his*$^+$ parents via transduction; selected strains also received the mutagenesis-enhancing plasmid pKM101 via conjugation. The frequency of spontaneous precise excision of Tn*10* was quantitated and found to vary considerably among strains of different genotypes, relevant to the precise excision frequency of a wild type. Profound increases in the precise excision frequency from this insertion site were found to occur in strains possessing mutations in the *uvr D156*, *lig-4*, *mut LI3*, and *mut H34* genes. The frequency of induced precise excision of Tn*10* was also quantitated following exposure to ultraviolet irradiation. A slight enhancing effect on this frequency over that of the wild type was found among those strains listed above. The effects of the chemical mutagens N-methyl-N′-nitro-N-nitroso guanidine and B-propiolactone on the precise excision frequency were also examined using spot-plate tests and were not found to influence this frequency.

Prostaglandin E_2 Synthesis by Adherent and Non-adherent Tumor Cells. COLLEEN MAY and M. RITA YOUNG, Department of Biology/Center for Medical Education, Ball State University, Muncie, Indiana 47306.——Tumor cells produce more prostaglandin E_2 (PGE_2) and are less adherent to artificial substrates than normal cells. Since reduced adherence contributes to metastasis of the tumor, this study proposes that there is a relationship between the amount of PGE_2 secreted by a tumor cell and the reduced adherence of more virulent tumors.

P815 mastocytoma cells were cultured *in vitro* under conditions which selected for adherent and non-adherent variants. The amount of PGE_2 in the culture supernatants of these cells of common origin but different degrees of adherence was quantitated by a radioimmunoassay for PGE_2.

In this study, tumor cells which were less adherent *in vitro* were shown to secrete more PGE_2 into the culture medium than more adherent tumor cell variants. These results suggest a correlation between secretion of PGE_2 and reduced adherence which is associated with metastasis of tumor cells.

Detection of Prostaglandin E_2 in the Sera of Tumor Bearing Mice. MICHAEL MCTAGUE and M. RITA YOUNG, Department of Biology/Center for Medical Education, Ball State University, Muncie, Indiana 47306.——Tumors may protect themselves from destruction by secreting products which suppress the immune responses of their hosts. Homogenates of tumor cells contain elevated levels of prostaglandin E_2 (PGE_2) which inhibits macrophage tumoricidal and lymphocyte immunoregulatory activities *in vitro*.

This study proposes that if PGE_2 synthesis by tumor cells occurs early in the course of tumor development, then serum levels of PGE_2 may be elevated at this time. Supernatants of cultured Lewis lung carcinoma (LLC) were examined by a

radioimmunoassay for PGE_2 to determine if tumor cells secrete PGE_2. Furthermore, the PGE_2 concentrations in sera of normal and LLC-bearing mice were compared and found to be elevated in tumor bearing mice.

The results of this study suggest that presence of tumor is associated with elevated serum PGE_2 levels. Thus, monitoring serum PGE_2 concentration could become a method for early tumor detection.

Characteristics of a More Efficient Glycerol Utilizing Mutant of *Rhodopseudomonas capsulata*. LOY PIKE, Department of Biological Sciences, Indiana University at South Bend, South Bend, Indiana 46615.——The purple nonsulfur photosynthetic bacterium *Rhodopseudomonas capsulata* is noted for its inability to grow with glycerol as the sole source of carbon. However, occasional strains are isolated from nature which are capable of utilizing glycerol as a nutrient. One such strain, designated SCJ, was capable of metabolizing glycerol under aerobic-dark or anaerobic-light (photosynthetic) conditions. This organism possessed a soluble glycerokinase and a particulate pyridine nucleotide independent glycereophosphate dehydrogenase. When strain SCJ was grown on glycerol agar plates two colony sizes were consistently seen, with the larger being the least numerous. This large colony type was isolated in pure culture, but all cultures cloned from a small colony produced some large colonies when plated on glycerol agar. The large colony type had a much faster growth rate on glycerol than did the small colony type. While the specific activities of the glycerophosphate dehydrogenases from the two colony types were virtually identical, the specific activity of the glycerokinase from the large colony type was markedly reduced from that of the small colony type. Indications are that the large colony type has a mutant glycerokinase which is no longer susceptible to feedback inhibition.

The Etiology of Wilt in *Helianthus annuus*. MARY LEE RICHESON, Department of Biological Sciences, Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805.——Two types of bacteria and a filamentous fungus were isolated from lesions inside the stem of *Helianthus annuus* showing wilt symptoms. Biochemical, morphological, and cultural tests indicated that one bacterial isolate was *Erwinia carotovora* var. *carotovora* and the other *Xanthomonas campestris*. The morphology of the fungus was similar to *Cephalosporium*. Suspensions of the bacterial cells or fungal spores were inoculated into the growing plants by scratch, spray, or injection at two week intervals until the plants blossomed. Results indicated that healthy young plants are resistant to infection by these organisms. As the plants matured, 20% of the plants inoculated by injection with *E. carotovora* collapsed at the infection site and the tissue above the injection site died. *E. carotovora* was isolated in large number from the diseased stem areas. Plants similarly inoculated at two week intervals with spores of *Cephalosporium* remained healthy until head set at which time necrotic areas covered with mycelium appeared on the stems. *X. campestris* inoculation caused the stem to weaken and bend but the plants did not die. These results indicate that both *E. carotovora* and *Cephalosporium* may be a cause of late season wilt syndrome in sunflower.

Bacterial Endotoxin Effects on Several Cell Lines in Culture

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Introduction

The *in vivo* biological effects of bacterial endotoxin (lipopolysaccharide, LPS) are well known and include fever, tissue damage, endotoxic shock and lethality (14). The basic mechanisms of cellular injury caused by endotoxin which lead to disseminated tissue damage and possible death of the host are not well known. *In vivo* studies have shown, for example, that the complement system is activated by endotoxin, but the significance of its possible role in inducing cellular injury is not clear (13).

Many of the *in vitro* studies of endotoxin effects on cellular structure or function have involved short-term cell cultures. For example, endotoxin inhibited adenosine triphosphatase activity of rabbit or human leukocytes (22). *In vitro* studies on the effects of endotoxin on guinea pig, rabbit and human macrophages migrating from organ explants also revealed endotoxin cytotoxicity (10). Bona (2) showed pinocytotic uptake of endotoxin by guinea pig macrophages and its transfer to autologous lymphocytes. In murine macrophages the stimulation of synthesis of both lysosomal and non-lysosomal enzymes was reported by Allison et al. (1), and Spitzer (20) found that isolated canine fat cells exposed to endotoxin *in vitro* show higher norepinephrine-stimulated lipolytic responses and higher cyclic adenosine monophosphate levels compared to control cells. There are a number of reports on endotoxin stimulation of murine bone marrow-derived lymphocytes (7,9,11,16). Interaction of endotoxin with human erythrocytes and the isolation and partial characterization of receptor material was reported by Springer et al. (21), although the relationship of the red blood cell receptor to the biological activities described above is unclear. Brailovsky et al. (3) used endotoxins with short core oligosaccharides (endotoxic glycolipids) and found *in vitro* growth inhibition of spontaneously or virally transformed rat embryo fibroblasts, but not untransformed fibroblasts. However, others failed to find cytotoxic effects when primary (adult and embryonic) cell cultures and established cell strains from rabbit, monkey, mouse and man were treated with up to 1 mg/ml endotoxin (8). In the present studies we demonstrate, using established murine and hamster cell lines, that endotoxin can markedly affect growth of some, but not all, of these cell lines in culture.

Materials and Methods

Cell cultures. Cell lines used in this study were obtained from several sources. Murine 3T3, SV3T3 and MSV3T3 were originally obtained from Dr. S. Aaronson, Viral Carcinogenesis Branch, National Cancer Institute. B16 melanoma (B16-F1) came from Dr. I.J. Fidler, NC1-Frederick Cancer Research Center, Frederick, Maryland. The S49 (S49-1) and CHO-K1-PRO lines were obtained from Dr. R. Hyman, The Salk Institute for Biological Studies, San Diego, California. BHK and PyBHK came from Dr. W. Eckhart of the Salk Institute. The RAW 117 line (RAW 117-P) was obtained from Dr. P. Ralph at the Salk Institute; the RAW 117-H10 variant line was selected from the parental strain (4). Cells were grown in Dulbec-

co's modified Eagle's medium (19) supplemented with 10% fetal bovine serum or 10% donor calf serum, nonessential amino acids and antibiotics as necessary (5) in plastic tissue culture or petri dishes.

Endotoxin. The gram-negative bacterial endotoxin used in our experiments was a lipopolysaccharide prepared by phenol-water extraction from *Salmonella typhosa* 0901 (Difco Laboratories, Detroit, Michigan). Biological activities of the endotoxin preparation were shown to be similar to purified lipopolysaccharide obtained from *Salmonella* (6,12) and were effective *in vitro* for inhibition of growth of certain tumor cells (17,18). Endotoxin (5 mg/ml) was heated in phosphate-buffered saline for 1 hr at 100°C, and aliquots were stored frozen at -20°C until just prior to thawing and dilution for use in the experiments.

Results

Several available cell lines were screened for obvious growth inhibition or morphological changes in the presence of endotoxin (Table I). No effects due to endotoxin were detected in most of the cell lines examined, even with the addition of up to 500 μg LPS/ml culture. With the murine lymphoma cell line S49 (a T-cell lymphoma), for example, the growth curve in the presence of LPS was essentially identical to growth of the cells in the control culture (no LPS added), as shown in Figure 1.

Murine cell lines markedly affected by endotoxin in these experiments were the lymphosarcoma cell line RAW 117-P and a malignant variant line RAW 117-H10 (Table I). Growth of the lymphosarcoma cell lines was inhibited early and the effect lasted for about three days in culture. There was an LPS dose-dependent effect (data not shown), and only 10 mcg LPS/ml inhibited growth of the cell lines 50% or more compared to control cultures (no LPS added) as shown in Figure 2. As seen in Figure 2, RAW 117-H10 cells were inhibited more by LPS (upper panel) than were the parental RAW 117-P cells (lower panel). Interestingly, after exposure to 10 mcg LPS/ml for three days, a "rebound" effect occurred in cultures of both cell lines, such that by the fourth day cultures in the presence of LPS had almost overtaken the control cultures.

The only hamster cell line affected by LPS was the Chinese hamster cell line CHO•K1•PRO; growth of this cell line was markedly inhibited by endotoxin (Table

TABLE I. *Endotoxin-mediated growth inhibition and morphological changes*

Cell Line	Animal Strain	Transforming Agent	Growth Inhibition	Mophological Changes
Mouse				
3T3	BALB/c	Untransformed	–	–
SV3T3	BALB/c	Simian Virus 40	–	–
MSV3T3	BALB/c	Murine Sarcoma Virus	–	–
B16 MELANOMA	C57BL/6J	Spontaneous	–	–
S49-1	BALB/c	Mineral Oil	–	–
RAW 117-P	BALB/c	Abelson Leukemia Virus	+	+/–
RAW 117-H10	BALB/c	Abelson Leukemia Virus	+	+/–
Hamster				
BHK		Untransformed	–	–
PyBHK		Polyoma Virus	–	–
CHO•K1•PRO		Untransformed	+	+

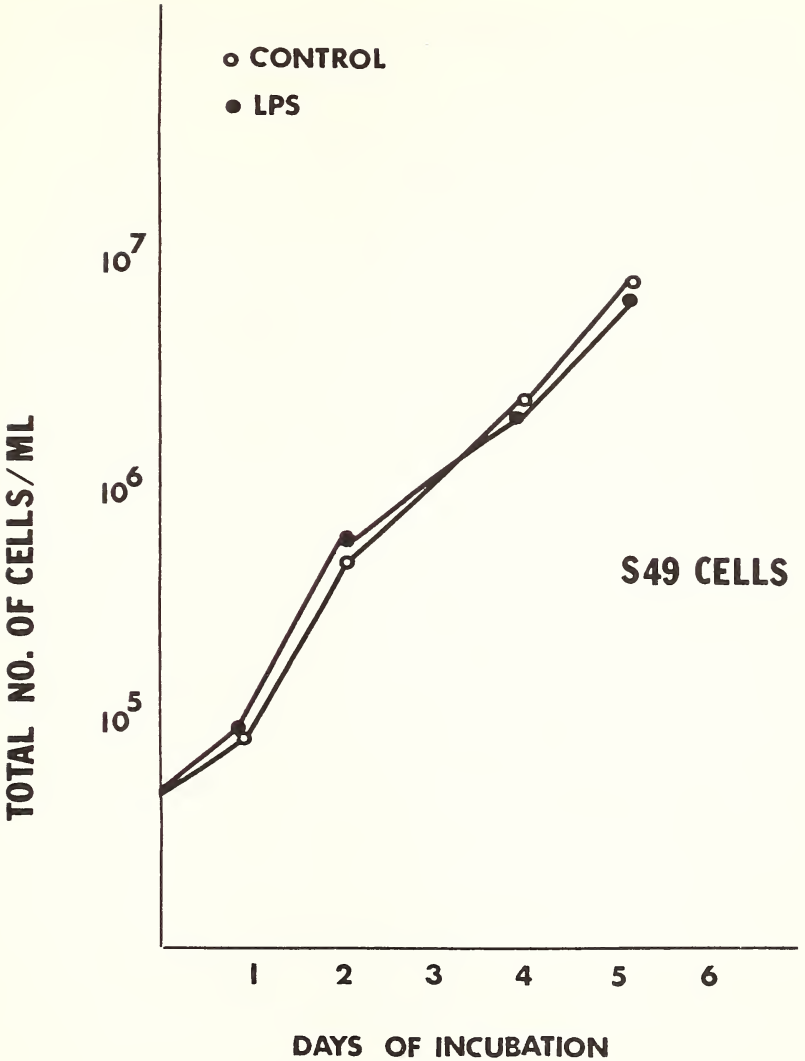

FIGURE 1. *Cells were plated at 5x10⁴/ml in a 60 mm petri dish and incubated in either 100 μg LPS/ml (final concentration), or no LPS was added (control). Each point represents the average of triplicate determinations of the number of cells/ml.*

I). Obvious endotoxin effects were not noted until after about four days' incubation at which time cell growth was almost completely inhibited (Figure 3). That this effect is due solely to cytotoxicity is unlikely, since cell populations remained greater than 90% viable by trypan blue dye exclusion after 7 days of endotoxin exposure. Interestingly, low concentrations (5 μg/ml) of endotoxin caused slight growth stimulation (Figure 3). Cells incubated in the presence of higher concentrations of

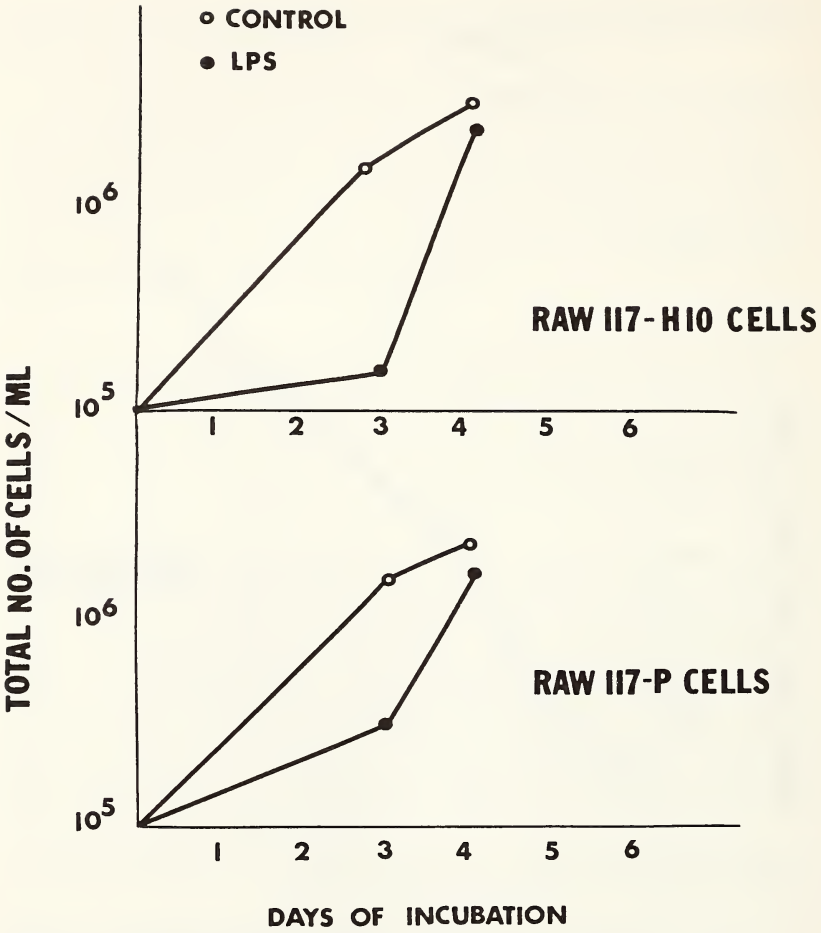

FIGURE 2. *Cells were plated at $1x10^5$/ml in a 60 mm petri dish and incubated in 10 μg LPS/ml (final concentration) or no LPS was added (control). Each point represents the average of triplicate determinations of the number of cells/ml.*

endotoxin (50 or 500 mcg/ml) were not stimulated and grew at about the same rate as control cells (no endotoxin added) until about 4 days' incubation, after which the endotoxin-treated cells exhibited growth inhibition (Figure 3).

CHO•K1•PRO cells incubated at a high endotoxin concentration (500 mcg/ml) for 7 days contained many large, light-refractile vesicles and had markedly altered cell shape and increased spreading (Figure 4) compared to control cells (Figure 5). Untreated cultures grew to confluency, while cells exposed to endotoxin remained quite sparse with the presence of several rounded cells (Figure 4). When the CHO•K1•PRO cells exposed to high levels of endotoxin were examined ultrastructurally, modifications were seen in the cytoplasms of the treated cells (data not shown). After 4 days' exposure to endotoxin, vesicles began to form in toxin-exposed cells which were not apparent in control untreated cells (data not shown).

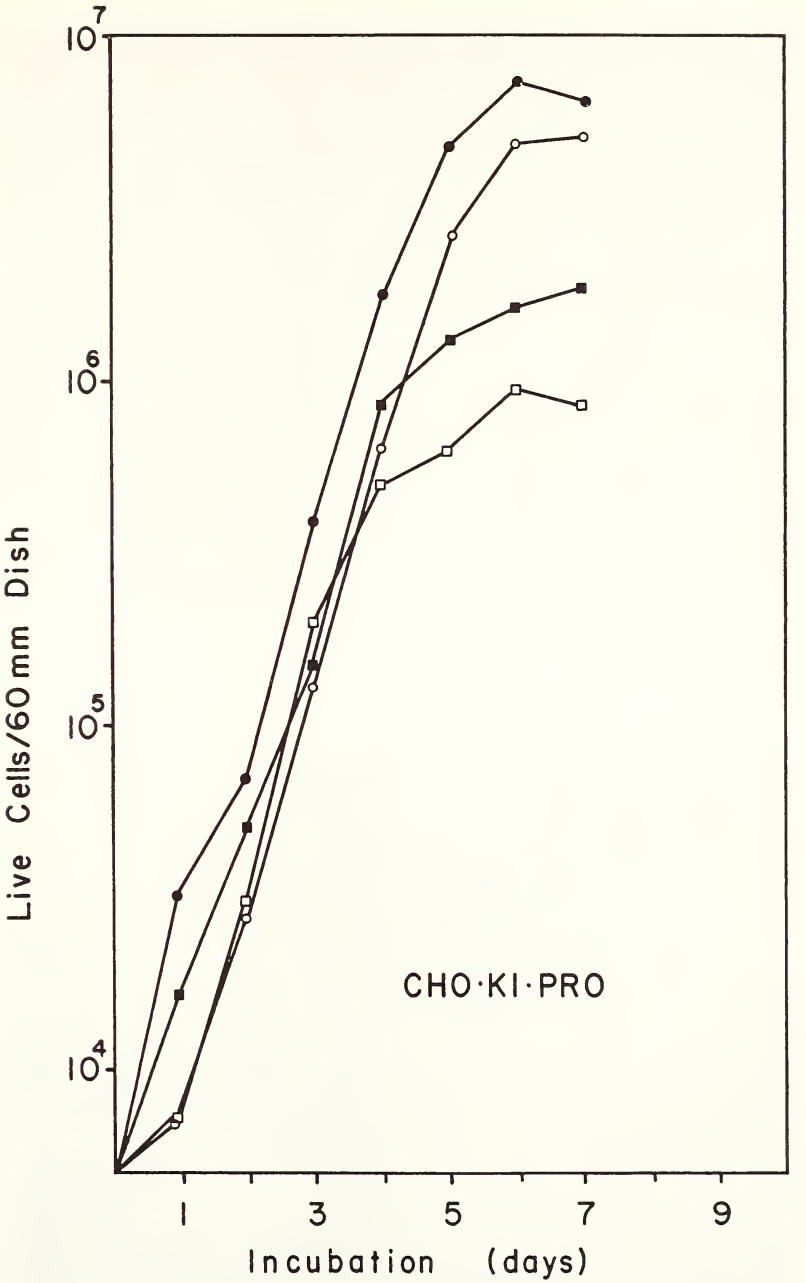

FIGURE 3. *Cells were plated at 5x10³/60 mm tissue culture dish and incubated in the indicated final concentrations of LPS. Each point represents the average of triplicate determinations of the number of cells.* ○ *controls, no LPS added;* • *5 μg LPS/ml;* ■ *50 μg LPS/ml;* □ *500 μg LPS/ml.*

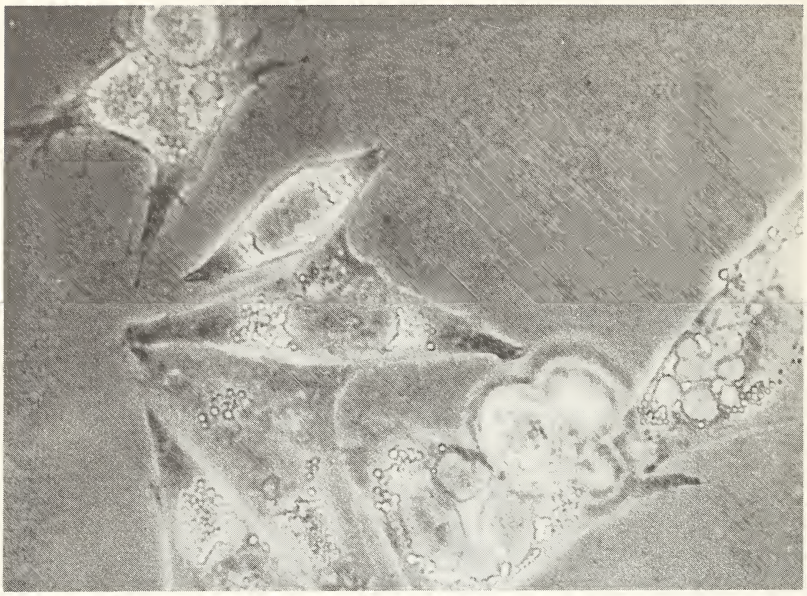

FIGURE 4. *CHO•K1•PRO cells incubated for 7 days, 500 μg LPS/ml. Phase contrast x 510.*

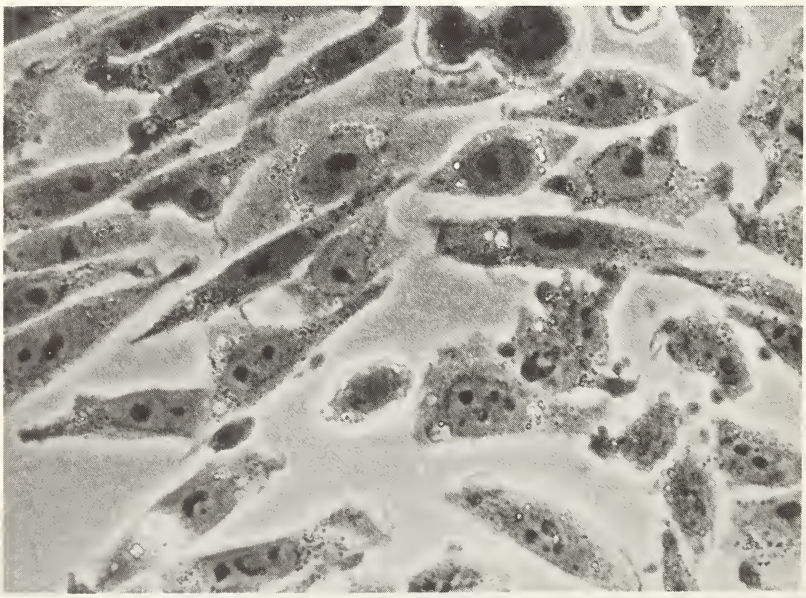

FIGURE 5. *Control (no LPS added) CHO•K1•PRO cells incubated for 7 days. Phase contrast x 510.*

By 7 days very large vacuoles were seen in ultrathin section of cells treated with endotoxin compared to control cells. The cellular modifications seen with light microscopy could thus be confirmed using electron microscopy; the ultrastructural studies will be the subject of a separate report.

Discussion

Although stimulatory (mitogenic) for mouse bone-marrow derived lymphocytes (B cells) *in vitro* (9), endotoxin is inhibitory for some murine B lymphoid tumor cells (18). In our studies with the RAW 117 lymphosarcoma cells, although growth was inhibited by LPS initially, a later period of growth stimulation was noted. Further work will be needed to see what may be involved in the stimulatory period. A number of possibilities exist, such as LPS depletion, emergence of an LPS inhibition-resistant population, or production of stimulatory products.

In other *in vitro* studies of cell growth inhibition by endotoxin the most marked growth inhibition of transormed rat embryo fibroblasts began after 3-4 days' incubation (3) much like our observations with CHO•K1•PRO cells. Similar to our investigations, cytotoxic effects were not seen; however, morphological alterations were not observed in the endotoxin-treated fibroblast cells (3). Cell shape changes (rounding) have been reported for Y-1 adrenal tumor cells exposed to a variety of gram-negative bacterial endotoxins (23), although endotoxin incubation times (13-16 hours) were less than those in the present report. It would be interesting if endotoxin also inhibits the growth of Y-1 adrenal tumor cells *in vivo*.

The *in vitro* endotoxin effects on inhibition of growth, induction of vacuolization and alteration of morphology of Chinese hamster ovary cells occurs only after prolonged endotoxin incubation with CHO•K1•PRO cells. These effects do not appear to be related to neoplastic transformation, because other untransformed/transformed hamster and mouse lines (Table I) are unaffected by similar concentrations of endotoxin.

Further work will be necessary to determine the mechanism(s) involved in growth inhibition of the CHO•K1•PRO and RAW 117 cell lines by LPS. It is interesting that "lag periods" similar to that observed in our studies between addition of LPS to CHO•K1•PRO cells and maximal cellular effects such as growth inhibition (3) or lymphocyte stimulation (4) have been observed. Additionally, mouse macrophages were shown to develop vacuoles after incubation with endotoxin (15), similar to what we observed in the CHO•K1•PRO cells. Thus, the possibility exists that LPS may exert analoguous effects *in vitro* on a variety of cell types.

Acknowledgments

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Effect of Experimentally Altered Thyroid States on the *In Vivo* Labeling of Red Blood Cells in the Rat

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Introduction

The *in vivo* procedure for labeling red blood cells with technetium-99m (Tc-99m) involves the intravenous injection of a reducing agent, such as stannous ion, followed by the intravenous injection of sodium [Tc-99m]pertechnetate (9). It is thought that Tc-99m enters the red blood cells, is reduced by the stannous ion present there, and binds to intracellular constituents (2,7).

Alteration of thyroid function may cause disruption of the red blood cell labeling process. Hypothyroidism and hyperthyroidism have been shown to produce changes in protein metabolism (10), which could affect the transport of pertechnetate since it is 65-80% bound to proteins (5). Hypothyroidism reduces the level of 2, 3-diphosphoglycerate in the blood and therefore its oxygen tension (3) which could change the amount of tin in the stannous ion state in the blood (8). The labeling of red blood cells could thus be affected. This study was performed to determine the effect of experimentally altered thyroid states on the efficiency of the labeling of red blood cells in rats using the *in vivo* technique.

Materials and Methods

Male Sprague-Dawley descendent rats (Laboratory Supply Co., Indianapolis, Indiana) with a weight range of 185-250 g were used. They were housed five to a cage by random assignment and were given free access to food and water. A 1-day period of acclimation was allowed before the experiment began.

A state of hypothyroidism was induced with propylthiouracil (PTU). The dosing solution was made fresh daily to contain 2 mg PTU/0.5 ml/rat. A state of hyperthyroidism was induced with L-thyroxine sodium pentahydrate (T4). The dosing solution was made fresh daily to contain 20 μg T4/0.5 ml/rat. Euthyroidism was maintained with 0.5 ml of 0.9% saline per rat daily. The drug pretreatments were administered by intraperitoneal injection and continued for 17 days (6).

Sodium [Tc-99m]pertechnetate was obtained daily from a commercial Mo-99/Tc-99m generator (Mallinckrodt, Inc., St. Louis, Missouri). The eluate was diluted with oxygen-free 0.9% saline to provide about 15 μCi of activity per milliliter. The volume injected into each rat was 0.5 ml, yielding an injected dose of about 7.5 μCi. An aliquot of the dosing solution was prepared for a standard so that the total activity injected into each rat could be accurately determined.

Stannous chloride solution was prepared daily by dissolving stannous chloride dihydrate in 16.7 ml of oxygen-free 6 *M* HCl and then adding sufficient oxygen-free doubly distilled water to make the total volume 100 ml. Immediately before use 0.1 ml of this solution was diluted to 25 ml with oxygen-free acidic (pH approximately 3) saline and then passed through a 0.22-μm cellulose filter to yield a solution of 42.1 μg Sn^{++} per milliliter. Oxygen purging was achieved by bubbling the solutions with nitrogen gas. The volume to be injected was based on rat weight so as to yield 50 μg Sn^{++} per kilogram of body weight.

The three treatment groups, hypothyroid, euthyroid, and hyperthyroid, each

contained 30 rats. Each treatment group was subdivided for five time periods, 0.5, 1, 2, 4, and 8 hours, each subgroup containing 6 rats. Initiation of the thyroid state induction treatment was timed so that five rats, one from each time period and one or two from each treatment group, completed the 17-day regimen simultaneously. The statistical design was a nonorthogonal, incomplete block design based on a pseudo-factorial construction (1).

On the 18th day, each of these five rats was given an intravenous injection of stannous chloride solution followed 25 min later by an intravenous injection of sodium [Tc-99m]pertechnetate solution, both injections being made into a tail vein. After the designated time period, each rat was anesthetized with ether, its chest was cut open, and blood was drained from its heart using a heparinized evacuated tube. Three milliliters of this blood was centrifuged at 1800 rpm for 5 min, the plasma layer was drawn off, and the erythrocytes were washed twice with 4 ml of 0.9% saline.

Weighed aliquots of whole blood and red blood cells as well as the standard prepared from the dosing solution were counted in a small well-type NaI(Tl) scintillation counter. The counting error did not exceed 1% at the 95% confidence level.

Results and Discussion

The percentages of the total activity injected per gram for whole blood and washed red blood cells were calculated using the activity present in the aliquots of these tissues and the activity present in the standard prepared from the solution injected. These percentages are shown in Table 1. Only 79 animals out of the original 90 were used to provide data for analysis. Of the 11 unused rats, one died of unknown causes during the labeling procedure, one was eliminated from the study due to its being unmanageable, and nine were discarded due to improper injection. The data were tested and found to be homogeneous ($P < 0.025$). A three way analysis of variance was then run to test for time, treatment, and blocking effects, all of which were found not to be significant ($P > 0.05$) (1).

TABLE 1. *Percentage of total Tc-99m activity injected per gram of tissue.*[a]

Time (hr)	Hypothyroid	Euthyroid	Hyperthyroid
	Whole Blood		
0.5	3.8 ± 0.7[b]	4.2 ± 0.8[b]	4.0 ± 0.5
1	4.0 ± 0.6	4.5 ± 0.4[b]	3.7 ± 0.7[b]
2	3.9 ± 0.4	3.5 ± 0.7[b]	3.6 ± 0.7[b]
4	4.0 ± 0.4[b]	3.3 ± 0.5[b]	3.6 ± 0.4
8	3.2 ± 0.5[c]	3.5 ± 0.8[b]	3.2 ± 0.2
	Red blood cells		
0.5	7.4 ± 1.8[b]	8.1 ± 1.5[b]	7.5 ± 1.2
1	8.0 ± 0.8	8.6 ± 1.0[b]	6.9 ± 1.3[b]
2	7.6 ± 0.5	6.8 ± 1.5[b]	6.6 ± 1.4[b]
4	7.4 ± 0.6[b]	6.3 ± 1.2[b]	6.7 ± 0.6
8	5.8 ± 0.7[c]	6.7 ± 1.2[b]	6.0 ± 0.3

[a]Mean ± standard deviation for six animals unless otherwise noted.

[b]Mean for five animals.

[c]Mean for four animals.

Since the blocking effect was not significant and since the statistical design assumed that there were no block-by-time, block-by-treatment, or block-by-time-by-treatment interactions, the data could be pooled across blocks and examined using a two way analysis of variance. In this analysis, the treatment effect remained insignificant but the effect of time became significant for both the whole blood and the red blood cells.

A Newman-Keuls test was run to find where significant differences ($P < 0.05$) occurred. The results are shown in Table 2. Although few significant differences are seen, there is a trend for the later time groups to have lower amounts of Tc-99m in both the whole blood and the red blood cells. This finding was not unexpected since the labeling of red blood cells with Tc-99m is known to degrade over time with a reported half-time of 19.5 hr (4). More interesting than the decrease in Tc-99m activity with time is the fact the decrease follows a similar pattern for all treatment groups, indicating that the altered thyroid states do not affect the rate of labeling or the rate of degradation of red blood cells.

The results of this study indicate that the experimentally altered thyroid states in the rat do not affect the labeling of red blood cells. If these states in the rat are physiologically identical to clinical hypothyroidism and hyperthyroidism in humans, the clinician need not be concerned with interference in the *in vivo* red blood cell labeling process due to altered thyroid state. Statistically identical labeling efficiencies can be expected in the hypothyroid, euthyroid, and hyperthyroid

TABLE 2. *Newman-Keuls multiple comparison of the treatment means.*

Treatment	Percentage of total Tc-99m injected per gram of tissue[a]				
	Whole blood				
Hypothyroid	1[a]	4	2	0.5	8
	4.0	4.0	3.9	3.8	3.2
Euthyroid	1	0.5	8	2	4
	4.5	4.2	3.5	3.5	3.3
Hyperthyroid	0.5	1	4	2	8
	4.0	3.7	3.6	3.6	3.2
	Red blood cells				
Hypothyroid	1	2	4	0.5	8
	8.0	7.6	7.4	7.4	5.8
Euthyroid	1	0.5	2	8	4
	8.6	8.1	6.8	6.7	6.3
Hyperthyroid	0.5	1	4	2	8
	7.5	6.9	6.6	6.6	5.9

[a]The designations represent the time intervals after injection of Tc-99m at which the rats were sacrificed (0.5, 1, 2, 4, and 8 hr). They are arranged in order of decreasing magnitude from left to right. Those underlined are not significantly different at $P > 0.05$ level. The mean value for each time is shown.

patient. If unusual labeling efficiencies occur in hypothyroid or hyperthyroid patients, the clinician should look elsewhere for a causal factor.

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PHYSICS AND ASTRONOMY

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ABSTRACTS

Thermistors: Their Construction and Applications. A. J. C. L. Hogarth, Department of Chemistry, DePauw University, Greencastle, Indiana 46135.——Although thermistors have been manufactured commercially for nearly forty years very little has been written about them in book form. Indeed, in most texts, their existence is merely inferred if it is mentioned at all. This is an unfortunate situation because thermistors are versatile components finding applications in fields as diverse as washing machine manufacture and meteorology.

'THERMISTOR', an acronym derived from THERMally sensitive resISTOR, was originally the name given to a solid state electronic component developed simultaneously in Holland and the U.S.A. during World War II. This device exhibited a very large negative coefficient if resistance over an extended temperature range. Today the name THERMISTOR implies a device made of semiconducting material that possesses an electrical conductivity highly sensitive to temperature.

A thermistor is constructed from a sintered ceramic composed of a mixture of several metallic oxides, the latter being chosen usually from the elements manganese, nickel, cobalt, copper and iron. By varying the composition and size of the semiconducting elements, resistance values between one and one million ohms may be achieved. The devices may be encapsulated or not as desired, and their physical size may vary considerably.

Their applications are diverse even without success at the obvious task of temperature sensing, they have a wide range of uses in electronic time delay circuits, as capacitors or inductors in low frequency oscillators, as surge suppressors, as liquid and gas flow monitors and many other areas.

The Determination of Sub-micron Particulates by the Howe-Wilson Method. Robert H. L. Howe, West Lafayette, Indiana 47906 and Ingi Ilgen, Istanbul Teknik Universitesi.——The mathematical approach for the determination of submicron particulates by the Howe-Wilson method is presented. Some experimental results are discussed.

Techniques of Measurement and Analysis in High Energy Muon-Nucleon Interactions in Nuclear Emulsion Targets. Gerald P. Thomas, Department of Physics and Astronomy, Ball State University, Muncie, Indiana 47306.——Techniques will be discussed for event scanning and selection, and measurement of multiplicities, ionizations and angles of secondaries. Particular attention will be paid to problems of angle measurement of the scattered lepton primary in the 1-150 GEV incident primary energy range. Also on-line, microcomputer-based, techniques for calculation of angles will be mentioned.

Optical Spectra, Shadow Band, Radio Frequency and Ionospheric Height Observations at the July 30, Total Solar Eclipse

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Introduction

A total solar eclipse provides an opportunity to study several interesting phenomena. Due to the rarity of total eclipses, the short time duration and the rapidly changing conditions during this short time period, many of these phenomena have not been studied thoroughly. Some of these phenomena are: 1) The optical spectrum just before, during and just after totality; 2) Shadow bands that occur a few minutes before and after totality; 3) Intensity variations of rf background at various frequencies; 4) Changes in the ionospheric layers of the earth's atmosphere.

The optical spectrum that is obtained just before and just after totality (called the flash spectrum) gives considerable information concerning the relative abundances of the elements at the sun's surface. The optical spectrum during totality, i.e., the spectrum of the corona, gives information concerning conditions such as temperature and pressure as well as relative abundances. Studies of the sun's surface and the corona are important in relationship to solar flares and the solar wind that have drastic effects upon the earth's atmospheric layers.

Shadow bands, faint light and dark bands that move across the earth's surface just before and after totality, are of considerable interest due to the fact they are probably caused by variations of some type in the earth's atmosphere (5). Previous studies of the orientation, spacing, velocity, optical wavelengths and relative intensities of shadow bands have been made in Brazil in 1966 (1), in North Carolina in 1970 (3) and in Nova Scotia in 1972 (2). The present work was an attempt to continue these types of studies.

Measurements of the variations of intensity of rf background at 3.85 MHz, 146.94 MHZ, 54.4MHz, 7.5 MHz and 550 KHz at the time of a total solar eclipse have been made previously (4). The present research continued these efforts at 5 MHz, 7.3550 MHz, 4.220 MHz and at a band of frequencies in the KHz range.

Ionospheric soundings were made during the 1973 eclipse in Surinam (4). This study showed that in the range of 3.5 to 5.5 MHz, rf reflection is changed drastically at the time of an eclipse showing that the ionosphere is profoundly affected by the lunar shadow. In the present research there was no way to make these soundings directly in the path of totality. However, records of ionospheric soundings were obtained from the Maui Field Station in the hopes that some effect could be seen at a considerable distance outside the path of totality within the penumbral track.

Equipment

To obtain optical spectra a TRAX Model 350 Field-Averaging spectrograph (from TRAX Instrument Corporation, Albuquerque, New Mexico) was attached to a Canon EF SLR 35-mm camera. This equipment was mounted on a tripod and was positioned at window 38 of the DC-9 Super 80 Hawaiian Airlines plane chartered by the Moonshadow Expeditions group (see Figure 1). The camera was set at f/2 and

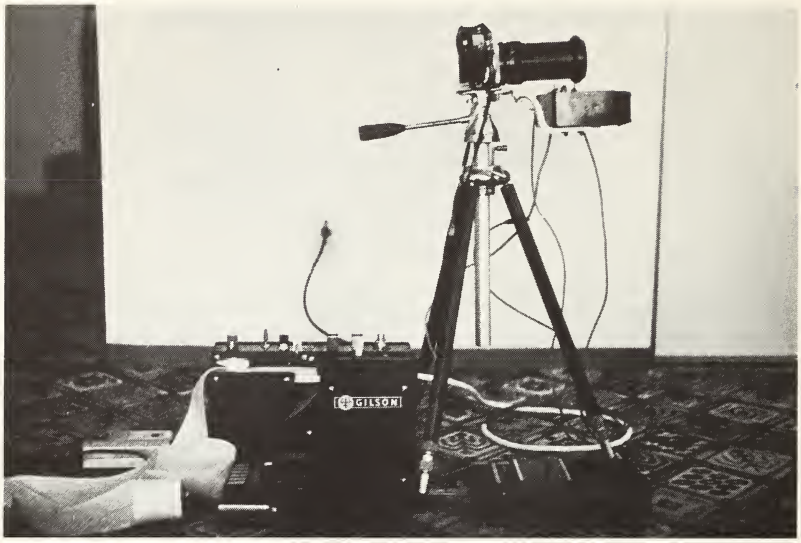

FIGURE 1. *TRAX spectrograph attached to a Canon EF SLR 35-mm camera with the photodetector system below.*

the focus was adjusted for sharp edges separating the ten different neutral density filters (a camera setting of 1.2 meters gave the sharpest edges). The ten neutral density filters range from 0.3 to 3.0, each step being a 2 to 1 ratio, i.e., one f-stop per step. This effectively provides 10 f-stops, i.e., ten different exposures at one time. The spectrograph has a wavelength range of 0.4 to 0.7 microns and a resolution of 300 Å. This instrument has just been developed by TRAX Instrument Corporation (Donald G. Carson, President) and this is the first time it has been used at an eclipse.

Shadow band studies aboard a jet aircraft presented problems such as the high speed of the airplane relative to the usually slow motion of the bands and no smooth white surface for visual and photographic work. In spite of these great difficulties it was decided that an attempt should be made to detect shadow bands on the right wing of the plane. The fact that a photograph suggesting shadow bands on an aircraft wing was published approximately ten years ago gave some encouragement. Brandon Crowe and Bill Jennings, technicians in the Department of Physics and Astronomy at Ball State, designed and fabricated a photoelectronic system consisting of six photodetectors, five of which were covered with narrow-band optical filters (see Figure 2). The uncovered photo detector was attached to a strip chart recorder while all six detectors were attached to a multiplex system (see Figure 3) which was connected to a cassette recorder. This system was "aimed" at the surface of the right wing.

Previous work has shown considerable variation of intensity of rf background during the partial phases and totality of solar eclipses, the type of variation depending upon the frequency of the rf background. This implies that even with the sun only partially covered there is a change in the ionization layers in the upper atmosphere. The most rapid electron density decay takes place in the lower

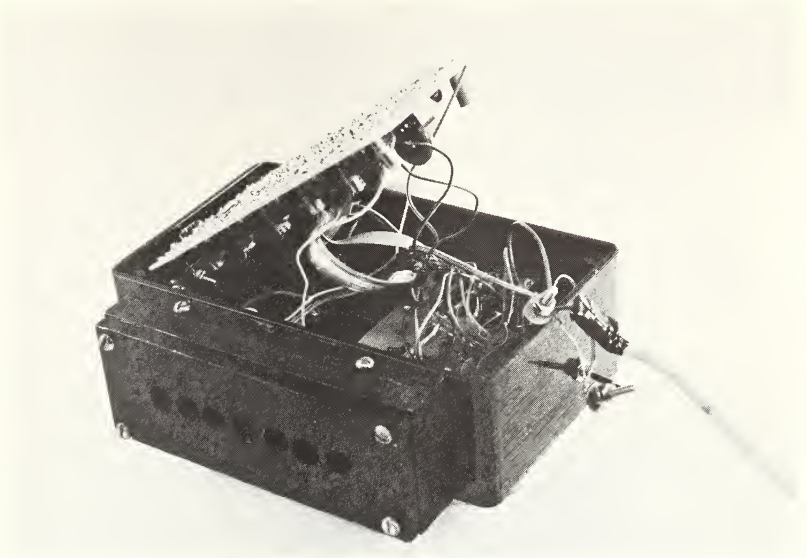

FIGURE 2. *Photoelectronic system for detecting light intensity variation (the shadow band effect) at different wavelengths.*

ionospheric region or "D" layer. The following four systems were set up to measure possible variations in rf background:

a) A Radio Shack Realistic TIMEKUBE WWV receiver, set at 5 MHz, was placed just below window number 38 with its antenna close to the window. The output of the receiver was fed into a strip chart recorder and a cassette recorder.

b) Mr. Joe F. Curado (KH6RM), Head of Avionics for Hawaiian Airlines, recorded rf background in Honolulu, using a Kenwood TS-8205 receiver (with an inverted Vee 45-foot antenna) attached to a RC-656JW/C cassette recorder. The receiver was set at 7.3550 MHz.

c) Mr. George Clark (KHGJJP), an official of the Honolulu Radio Club, recorded rf background in Honolulu, at 4.020 MHz on cassette tape.

d) A low frequency receiver, built by Bob's Electronic Service, Fort Lauderdale, Florida (advertised as a "solar flare detector") was operated the day before the eclipse, on eclipse day and several days following the eclipse. This equipment consists of a receiver tunable from 27 to 60 KHz connected to a 0-200 microampere Model 288 Rustrak recorder. As stated in the instruction manual "this receiver monitors atmospheric noises in the D ionospheric layer for sudden enhancements due to solar flares". Thus this equipment is a natural for measuring changes in the rf background during eclipses. This equipment was operated at Makaha Valley Plantation, Waianae, Oahu, Hawaii.

After the eclipse, numerical data from ionospheric sounding was obtained from Mr. David Tanaka of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Cooperating Observation Branch, Maui Field

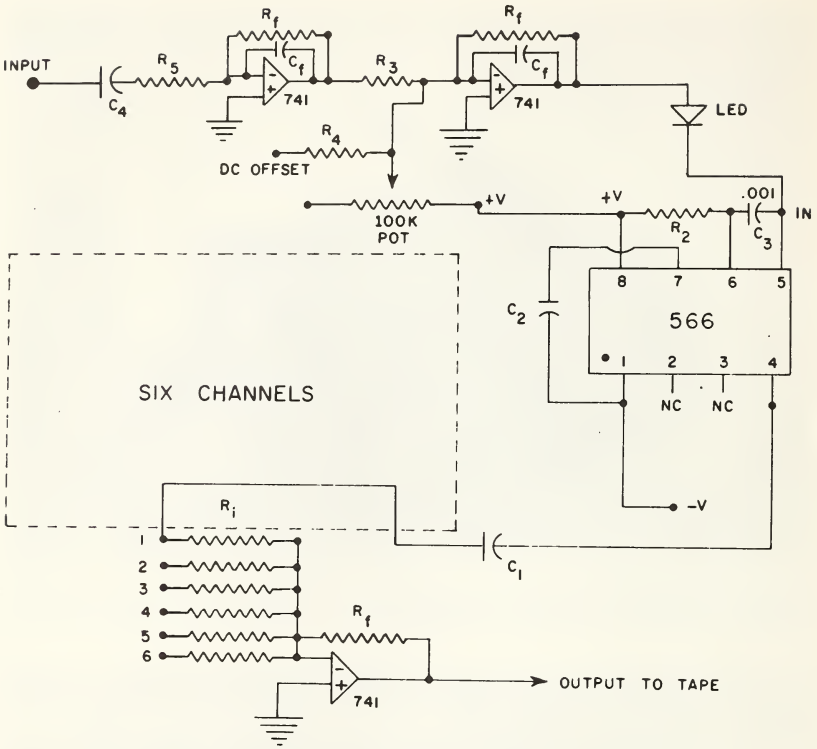

FIGURE 3. *The electronics for the photoelectronic system indicating the multiplex system, one channel shown.*

Station, Puunene, Maui, Hawaii. Although this location was several hundred miles outside the path of totality it was hoped that some "eclipse effect" could be seen in the data.

Results and Discussion

Five 15-second exposures were taken, with the TRAX spectrograph, starting approximately 30 seconds before totality. The TRI-X film shows the ten steps of the neutral density filter confirming that the 15-second exposure time, suggested by Donald Carson, was quite appropriate. Spectra are indicated on the five exposures. The spectrograph, being just developed, needs further calibration for these data to be meaningful. It is felt that this first trial is a good beginning towards more extensive use of the TRAX spectrograph at future eclipses.

As mentioned previously, the possibility of observing shadow bands aboard an aircraft is not great. An interesting visual observation, possibly related to shadow bands is reported in the following paper. The results from the photoelectronic system described above are quite complex. During the actual data taking it was noted that the part of the system consisting of the uncovered photodetector connected directly to the strip chart recorder gave very large amplitude and very high frequency signals. Superimposed on this was an overall large increase and decrease

of signal with a peiod of two to three seconds. The complexity of the strip chart recording made analysis quite difficult which suggests the need for further development of this part of the system for the next eclipse. It is possible the photoelectronic system was picking up signals from other electronic instruments aboard the aircraft.

The results from the four rf experiments are as follows:

a) From 7:00 p.m. to 7:11 p.m. rf background from the Radio Shack WWV receiver, set at 5 MHz, increased approximately 50% (see Figure 4). This can possibly be explained by a decrease in the electron density in the D layer resulting in a decrease in the critical frequency. The critical frequency is directly proportional to the ionospheric electron density; at or below the critical frequency the wave is totally reflected.

b) The cassette tape recording of rf background at 7.3550 MHz, made by Mr. Joe F. Curado, was analyzed by recording it on a strip chart recorder. This recording shows some interesting variations in rf intensity. Mr. Curado reported that in his 20 years of amateur radio work he had never heard this band die down as it did two or three times during the recording.

c) The cassette tape recording of rf background at 4.020 MHz, made by Mr. George Clark was also analyzed by using a strip chart recorder. This recording shows the same variations that are in the previous recording at 7.3550 MHz.

d) The results from the low frequency receiver are quite interesting. Figure 5 shows the variation in rf background on July 29, July 30 and August 3. On all three days the pattern is quite similar during the afternoon and

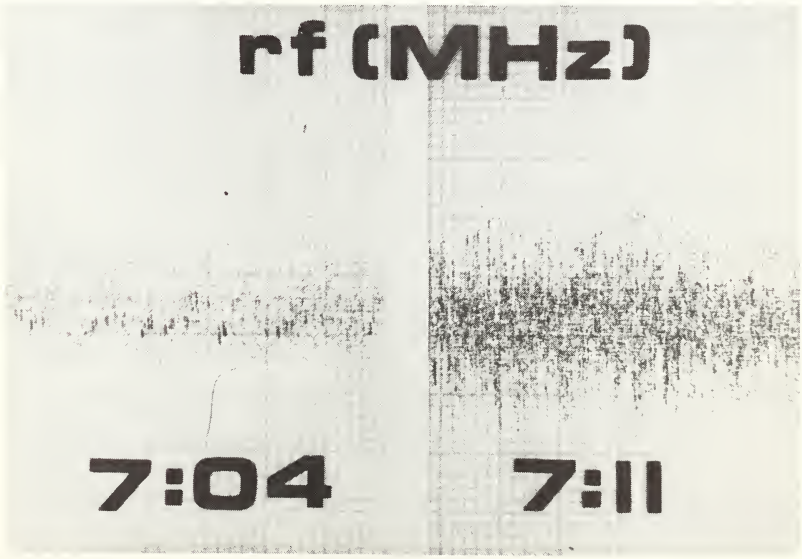

FIGURE 4. *Intensity of rf background (at 5 MHz) at 7:04 p.m. on the left and at 7:11 p.m. on the right showing a 50% increase in intensity.*

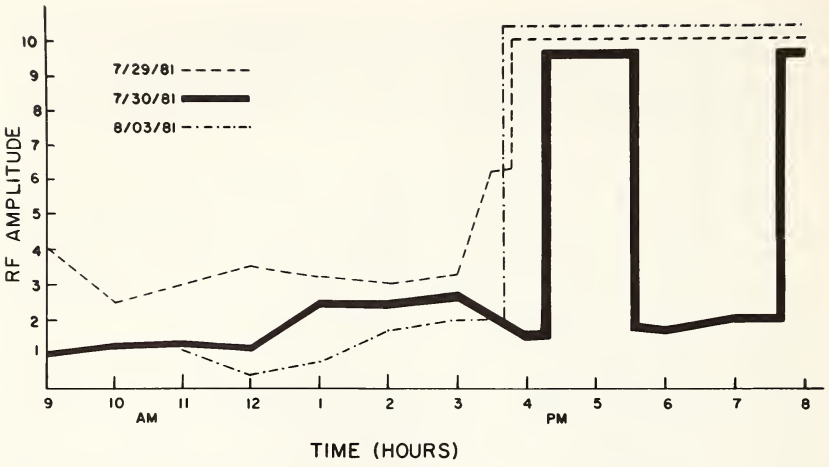

FIGURE 5. *Variation in rf intensity at low frequency on July 29, July 30 and August 3, 1981. Note the drastic decrease in rf background on eclipse day, July 30 as compared with the other two days.*

early evening. However, later in the evening the two non-eclipse day patterns are quite similar but on the eclipse day, July 30, there is a drastic reduction in rf intensity. This indicates that the eclipse has a great effect on the ionospheric D layer in the upper atmosphere (5) resulting from attenuation of solar ultraviolet emissions.

The ionospheric sounding data are quite extensive. the soundings were made several hundred miles outside the path of totality. These data have not been completely analyzed at the time of writing. However, an "eclipse effect" may be present as the D layer decay is proportional to the amount of the sun covered by the moon, and would occur within the atmospheric path crossed by the moon's penumbra.

Summary and Conclusions

The conclusions from this research are:

1) The TRAX spectrograph may be a useful tool to analyze optical spectra of eclipses. If properly calibrated this instrument will produce exposures showing relative strengths of various spectral regions. For example, such information might be useful in analysing relative intensities in the chromospheric flash spectrum. Further refinements and careful documentation of times of exposures will be needed at subsequent eclipses.

2) Shadow band detection aboard a jet aircraft is difficult. The operation of the photoelectronic system in a "real" situation was of great value for developing refinements in the equipment and developing operational procedures at future eclipses. It is felt that ground observations using this equipment, with precautions against outside electrical interference, should give very good results.

3) The results of the rf background measurements at various frequencies are of considerable interest and suggest a need for further development of equipment for eclipses in the future. The 50% increase in rf intensity

at 5 MHz over the relatively short time period of 7 minutes preceeding totality, and the drastic decrease in rf intensity at low frequencies suggest that more studies should be make at many different frequencies and over longer periods of time both before and after the total phase of the eclipse. Also it would be of interest to measure rf background at identical frequencies and with identical equipment at several locations in and out of the path of totality. Other possibilities are various coordinated effects in which an identifiable signal is sent from some distance outside the path of totality with various receivers, tuned to receive this signal, placed at various positions both in and outside the path of totality.

4) From the work in Surinam, and this project, it would appear the ionospheric soundings need to be made in the path of totality. However, it would be of extreme interest to do both simultaneously at some future eclipse.

Acknowledgments

Special thanks go to Dr. Jay Pasachoff who informed us about the Moonshadow Expeditions group and to Steve Edberg, the director of the group. Thanks also go to Steve Greenberg, Patty Winter, Bay Stewert Leber and Serina Leber for many helpful discussions in Hawaii.

The essential preparatory work done by Brandon Crowe and Bill Jennings and the expertise of Dr. Paul Errington in developing the photoelectronic system are deeply appreciated.

The logistics of placing our equipment aboard the plane and making sure it would not interfere with the navigation equipment would have been impossible without Mr. Joe Curado's assistance. He and his most able technician, Stan Okazaki, provided invaluable help.

This eclipse research was partially supported by a Ball State Alumni Association Study-Abroad Program Grant, a grant from Indiana Academy of Science and Ball State Department of Physics and Astromony funds.

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Test of Nuclear Explosive in China Viewed from Muncie

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Introduction

On October 16, 1980, at 12:30 a.m. E.D.T., the People's Republic of China detonated a nuclear weapon to celebrate the 16th anniversary of their first detonation of a nuclear explosive. The burst in the atmosphere above the Lop Nor region in China was estimated at 200 kilotons to one megaton of T.N.T. in accounts published in the United States.

Two types of nuclear reactions are used in nuclear weapons, namely fission and fusion. The fission process occurs when a neutron enters the nucleus of a fissionable atom, ^{235}U or ^{239}Pu, and causes the nucleus to split into two smaller parts. More than 100 unstable, primary isotopes are produced during fission reactions. The fragments are generally unstable and undergo an average of three decays before reaching a stable state. Their half-lives vary from a fraction of a second to many years.

Fusion is the process of uniting a pair of light nuclei to form a nucleus of a heavier atom. Two isotopes of hydrogen, deuterium and tritium, are used extensively in the fusion process. Nuclear fusion explosions are triggered by very high temperatures produced by critical fission reactions. Fusion reactions between deuterium and tritium liberate high energy neutrons. These neutrons cause fission in isotopes of uranium or plutonium, which do not fission when they absorb slow neutrons. Thus, an explosive device using ^{235}U to trigger a thermonuclear explosion can be surrounded by a casing of plutonium or uranium to increase its explosive yield. Eighty percent of the explosive intensity may result from the final fissioning of the blanket of uranium or plutonium.

The characteristics of the fallout produced by a nuclear explosion depend on the type of weapon used and the test conditions. Depending on the height of the burst and type of terrain below, varying amounts of debris will be sucked into the center of the blast. In this central region, all the material vaporizes and a cloud is formed from the debris, casing, and explosive itself. As expansion takes place, cooling begins, and the vapor condenses to form a radioactive cloud containing many particles. The speed at which the radioactive cloud descends depends upon the meteorological conditions and the energy yield of the weapon. Some of the particles will fall out within the first 100 miles of the burst. Thus prompt fallout is extremely radioactive and will cause most deaths. The remaining particles in the cloud flow with global air currents and continue to fall from the cloud as it passes over the earth (2).

Experimental Details

Sampling began on October 18, 1980, just two days after the explosion. Air samples were collected using a high-volume air sampler which was mounted on the roof of Cooper Science Complex at Ball State University, Muncie, Indiana. Sampling was conducted from October 18th to 27th. The air filter was removed from the sampler every 24 hours and examined within the following week for gamma activity using a lithium-drifted germanium detector. Each filter was weighed before and

after sampling and each sample contained approximately 20,000 mg of particulates. Spectra were recorded in a Nuclear Data 4410 multichannel analyzer and then transfered to the Dec System 10 computer for editing, plotting, and making corrections for the efficiencies of the detector. Relative gamma activities were computed from the areas under the gamma peaks.

The following fission fragments and heavy elements were clearly identified in the gamma-ray spectra: ^{95}Zr, ^{111}Ag, ^{207}Bi, ^{208}Tl, ^{214}Bi. Table 1 lists activities of three isotopes as a function of time when the samples were collected. (Only statistical errors are shown in the table.).

The initial data on the fallout, which demonstrated the passage of the cloud over Muncie, were troubled with high laboratory background. A later run, also collected from the roof of Cooper, contained a larger sample and produced a spectrum with less background. This spectrum was recorded on January 10, 1981, 86 days after the published date of the detonation. Four gamma peaks were identified as the activity due to fission fragments. The counts contained in each of these peaks were corrected for branching ratios to represent relative activity due to each isotope at the time of the explosion.

Results and Conclusion

The experimental data indicate that the fallout cloud reached Muncie, Indiana, on October 23rd. This is consistent with a report in the Muncie Star on October 19th, which indicated the cloud should be over the west coast that day and with the date observed by Lewellyn et. al. (3) in 1976 for a similar Chinese test. On October 23rd and 24th, the main center of the cloud appeared. A heavy rain on the 24th accounts for the increase of activity on that day and its subsequent decline. Sampling was halted on the 27th of October because of equipment failure.

In order to verify that the observed activity was indeed due to the Chinese test, the ratio of activity observed for ^{95}Nb to the activity of its parent ^{95}Zr was computed for the cleaner spectrum recorded in January. The ratio was used to calculate the time elapsed since the detonation. This calculation yielded 82 days ± 8 days, which is in agreement with the time known to have elapsed since the explosion. The quoted uncertainty includes errors in the efficiency calibration of the detector and the branching ratios.

The time elapsed since the detonation was then used to calculate the relative initial abundance of the, isotopes ^{95}Zr, ^{103}Ru and ^{141}Ce. No attempt was made to compute absolute yields from the fallout data, since they depend on weather condi-

TABLE 1 *Activities in counts per hour of three isotopes*

DATE	^{95}Zr	^{208}Tl	^{207}Bi
Oct 18-19			1837 ± 15
Oct 19-20			
Oct 20-21	706 ± 87		1479 ± 15
Oct 21-22	397 ± 60	163 ± 51	1750 ± 13
Oct 22-23	106 ± 57	118 ± 47	1332 ± 13
Oct 23-24	583 ± 74	352 ± 83	2394 ± 14
Oct 24-25			1863 ± 14
Oct 25-26			1721 ± 14
Oct 26-27			1463 ± 13

TABLE 2 *Relative Abundance of Fission Fragments for Different Fission Processes*

	^{235}U	^{239}Pu	Exp
$^{95}Zr/^{103}Ru$	2.09	1.02	1.88 ± .27
$^{141}Ce/^{95}Zr$	.97	.88	.21 ± .03
$^{141}Ce/^{103}Ru$	2.00	.90	.39 ± .06

tions and other unknown factors, such as the height of the burst. The ratio of ^{95}Zr to ^{103}Ru provides an indication of the particular material which fissioned in the test (1). Table 2 shows the results of this study compared to the isotopic ratios expected for the fission of ^{235}U and ^{239}Pu, respectively. This information leads one to conclude that the current Chinese explosion relied on the fission of ^{235}U. This is in agreement with the results found by Smith, Ward and Wesick, of Indiana University, for a bomb detonated by the Chinese at Lop Nor China on November 17, 1976 (4). A marked depletion of ^{141}Ce relative to ^{95}Zr and ^{103}Ru is noted in the fallout. This depletion is expected since ^{141}Ce is the end product of a decay chain involving ^{141}Xe, a noble gas, and ^{141}Cs which is volatile. Both of these nuclides live long enough for particles in the fallout to condense from the test cloud. Since the gas and the volatile element would not condense, the fallout particles would be expected to be deficient in these isotopes and their daughter ^{141}Ce.

In conclusion it is believed that the bomb detonation observed in this study was not pure fission since it was so large. A fission-fusion bomb would not have yielded the heavy elements that were observed and so it must have been a fission-fusion-fission explosion with the majority of the fission due to ^{235}U.

According to data released by the National Radiological Protection Board, fallout from nuclear testing increases background radiation by about 1%. This test produced tracer additions to the normal background on the order of another percent which present no significant health hazard, as long as the Chinese only test every 16 years.

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Photographic and Visual Studies of the July 30, 1981 Total Solar Eclipse from 37,000 Feet

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Introduction

Photographing an eclipse from an aircraft creates distinct advantages and disadvantages relative to ground-based observations. Among the disadvantages are the unavoidable vibrations and motions of the aircraft, a very restrictive view of the sky, and having to observe through a multi-layer reflection prone plexiglass window.

However, observing from a high altitude aircraft practically eliminates interference from clouds and haze. The sun was only about 3° above a sea-level horizon when the moon's umbra swept over the Moonshadow aircraft. From the aircraft's altitude of 37,000 feet the sun was approximately 6° above the apparent horizon, well above any interfering weather. The many clouds seen dotting the Pacific far below would have made ship-based observations difficult if not impossible. The low altitude of the sun combined with the height of the aircraft also provided a dramatic view of the rapidly moving umbral cone.

Visual Impressions

Visually the eclipse was an awesome experience. Approximately an hour before totality, first contact was observed as the moon began to cover the solar disk, starting at the four o'clock position. The partial phases were observed through aluminized mylar plastic.

As totality approached, the sky began to grow noticeably darker. Around 7:12 p.m., Hawaiian time, the sun was a brilliant wire-thin crescent above the cloud speckled Pacific, 37,000 feet below. Suddenly the lunar umbra appeared, rushing toward the aircraft across the ocean like a curtain of darkness. The solar crescent thinned into a brilliant "diamond ring" at the one o'clock position, heralding the appearance of the corona.

At 7:13 p.m. the sun was completely covered by the moon. During the brief 17-second totality the prominent umbral cone was visible moving rapidly from right to left, the clouds below tinted an eerie salmon hue with chromospheric hydrogen-alpha emission.

To the eye, the corona appeared small with much fine structure, and somewhat blue in color. Photographically, the corona was much larger.

Totality ended with a second diamond ring at the four o'clock position. The proximity of the first and second diamond rings indicated that the aircraft was not in the exact center of the umbral track. At the center of the track the diamond rings would have been 180 degrees apart. An observer located at the edge of the track would have observed but one prolonged diamond ring.

The duration of the diamond rings was extended as observed from the Moonshadow aircraft, lasting for approximately 20 seconds each. Due to the high altitude, the bright inner corona was visible during the diamond ring phases, as well as during totality.

No shadow bands were visually detected on any part of the aircraft immediately before or after totality. Movie footage taken of the right wing by Joyce Hults also failed to show any shadow bands. About 15 minutes after totality, distinct ripples were seen for about 3 seconds, moving away from the fuselage on the right wing. By this time the aircraft was at a lower altitude, and had turned so that the sun was on the left, casting a shadow of the fuselage on the right wing. The ripples appeared beyond the fuselage shadow, parallel to the shadow, and moved with a velocity of at least 2 or 3 meters per second toward the wing tip.

The ripples were certainly not shadow bands in the usual sense as they occurred too long after totality. Shadow bands are usually seen a minute or two before and after totality, and are most likely atmospheric density waves projected upon the landscape by the thin solar crescent. The solar crescent is normally too large to project shadow bands 15 minutes after totality. The sun in this case was very near the apparent horizon and seen through a great thickness of atmosphere. The observed ripples could have been due to atmospheric turbulance or diffraction as the sun was occulted by a cloud. At least one other observer has reported phenomena similar to shadow bands during a normal sunset (1).

Photographic Results

Figures 1,2, and 3 were taken with a Nikkormat Ftn camera and a 50mm lens. The original exposures were made on Ektachrome 400 slide film, using a time of 1/250 second and a focal ratio of f/2. These photographs were printed from black and white internegatives, which were made from the original slides.

Figure 1 shows the initial diamond ring at the start of totality. The edge of the umbral core is visible at the lower right. Totality began at approximately 7:13 pm July 30, 1981, Hawaiian time.

FIGURE 1. *The initial diamond ring just before totality at 7:13 pm Hawaiian time. The edge of the umbral cone is visible at the lower right.*

FIGURE 2. *Totality. As in Figure 1, the edge of the umbral cone is visible at the lower right.*

FIGURE 3. *The end of totality as the umbra moves off to the upper left. Clouds over the Pacific 37,000 feet below are tinted an eerie salmon hue by chromospheric hydrogen-alpha light. The right wing of the aircraft is visible at the lower right.*

FIGURE 4. *The first diamond ring. A Cibachrome print made from the Super 8 movie taken with the Nikon R-8 on Ektachrome 160 film.*

Totality is shown in Figure 2. Again the edge of the umbral cone is visible at the lower right.

The dramatic end of totality is shown in Figure 3, taken approximately 17 seconds after Figure 1. The umbral cone is moving off to the upper left. Chromospheric hydrogen-alpha light at the edge of the umbra tinted the clouds 37,000 feet below an eerie salmon hue. The white splotches seen in Figures 1 and 3 are unavoidable reflections caused by the plexiglas window of the aircraft.

Figures 4 and 5 show the first and second diamond rings. These Cibachrome

FIGURE 5. *The second diamond ring. A Cibachrome print from the Super 8 movie. The authors saw approximately 17 seconds of totality between the end of the first diamond ring and the start of the second.*

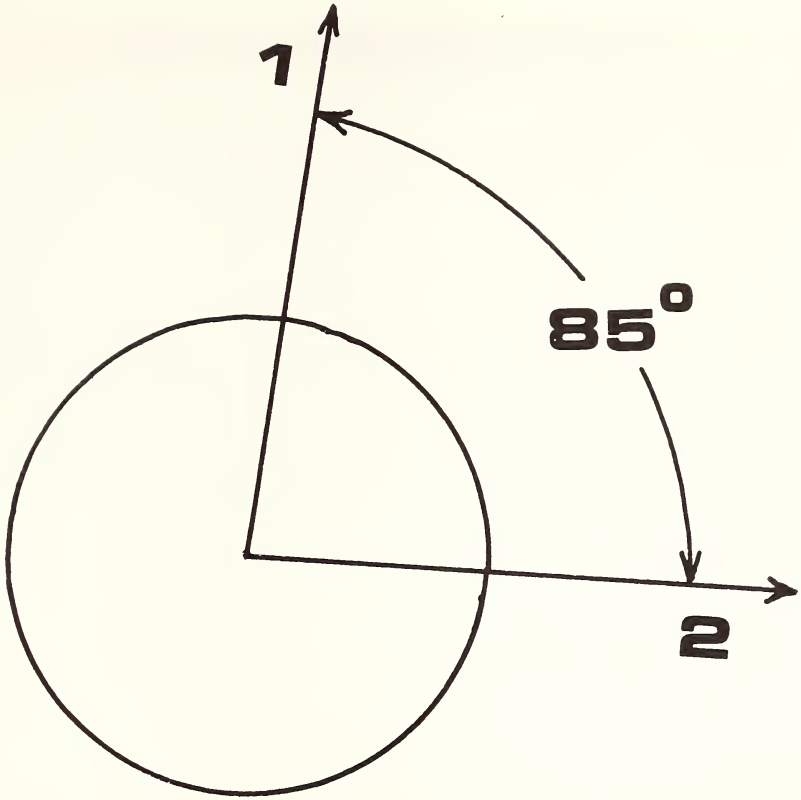

FIGURE 6. *The angle between the diamond rings illustrated. Arrows 1 and 2 show the positions of the 1st and 2nd diamond rings, respectively.*

prints were made from a Super-8 movie taken with a Nikon R-8 camera on Ektachrome 160 film.

Figure 6 illustrates that the angle between the diamond rings was approximately 85 degrees, indicating that the aircraft was not centrally located in the umbral track during the eclipse.

Acknowledgments

The authors are indebted to Dr. Jay Pasachoff who informed us about the Moonshadow Expedition group, and to Steve Edberg, the expedition Director. Thanks are also extended to Mr. Joe Curado, Director of Avionics, Hawaiian Airlines. Mrs. Joyce Hults took a movie of the aircraft wing in an attempt to detect shadow bands. Thanks also go to Bay Stewart Leber and Serina Leber for many helpful discussions in Hawaii.

Financial aid was provided by a Ball State University Alumni Association Study-Abroad Program Grant, a grant from the Indiana Academy of Science, and by funds from the Ball State University Department of Physics and Astronomy.

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Determination of Radioactive Emissions from Coal-fired Power Plants in Indiana

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Introduction

In a recent visit to Ball State University, Dr. Hugh Spencer, a professor of environmental engineering at the University of Louisville, pointed out that in the last 50 years, coal-fired electric plants along the mainstream of the Ohio River have increased from 200 MWe to approximately 30,000 MWe. It is well known that coal-fired power plants emit pollutants into the air. Some of these pollutants are radionuclides that are contained in the coal that is burned. Two separate studies of radionuclides from coal-fired power plants produced conflicting results. Keiger and Jacobs (1) studied samples of coal, flyash, bottom ash, and scrubber sludge collected from different regions of the United States. These samples where analyzed for radium, thorium, and uranium and showed no immediate health risk. On the other hand, a similar study by Styron and Robinson (2) conducted in Miamisburg, Ohio, indicated that a hazard does exist and further studies should be made.

In view of these conflicting reports it was decided to investigate the release of radioactive nuclides by coal-fired power plants in Indiana. Our sampling technique was the collection of air samples via high volume air sample filter papers in the vicinity of coal-fired power plants.

Experimental Procedures

In selecting sampling locations in Indiana we chose Ball State University and Indiana University because it was easy to put the air sampler near the smoke stacks of the power plants in these locations. These locations are not electric plants, but instead produce steam for heating. Since coal burning in these plants is the same as in electric plants they can be studied for emissions from coal-burning. The Fairbanks 400 MW Breed plant was also chosen because it was isolated from other power plants. It is located southwest of Terre Haute. Despite the cooperation of the Indiana and Michigan public relations officer in Muncie, the power plant officials would not allow air samples to be collected on the grounds of the Fairbanks plant. A neighbor allowed the air sampler to be set up in his yard which was within two miles of the Breed plant.

The final sampling location was in Markleville. The Markleville area doesn't contain a power plant and was used as a control sample for comparison with sampling sites close to coal-fired plants.

Detailed data on each plant is given in Table 1. Indiana University and Fairbanks both use mechanical dust collectors and electrostatic precipitators. Ball State has no emission control system.

The sampling system consisted of a high volume air sampler redesigned for easy transportation to the different sites. At each location, a preweighed filter was placed in the sampler and exposed continuously for seven days. An average of 0.6 grams of particulate matter was collected in each sample. Filters were folded to a three inch square and taped to a lithium drifted germanium detector. Gamma spectra were collected for forty eight hours in a Nuclear Data 4410 multichannel

TABLE 1 *Data on coal-burning plants sampled*

Plant	Ball State	Indiana University	Fairbanks
Type of System	¾ x #10 mesh coal	1¼ x #10 mesh coal, Hoffman spreaders	Pulverized coal
Efficiency Rating	75%	85%	35%
Type of Emission Control	None	Mechanical dust collector Electrostatic precipitators	Mechanical dust collector Electrostatic precipitators
Type of Coal	Indiana (High Sulfur) Washed	Indiana (2.5% Sulfur) Washed	Indiana Coal Unwashed

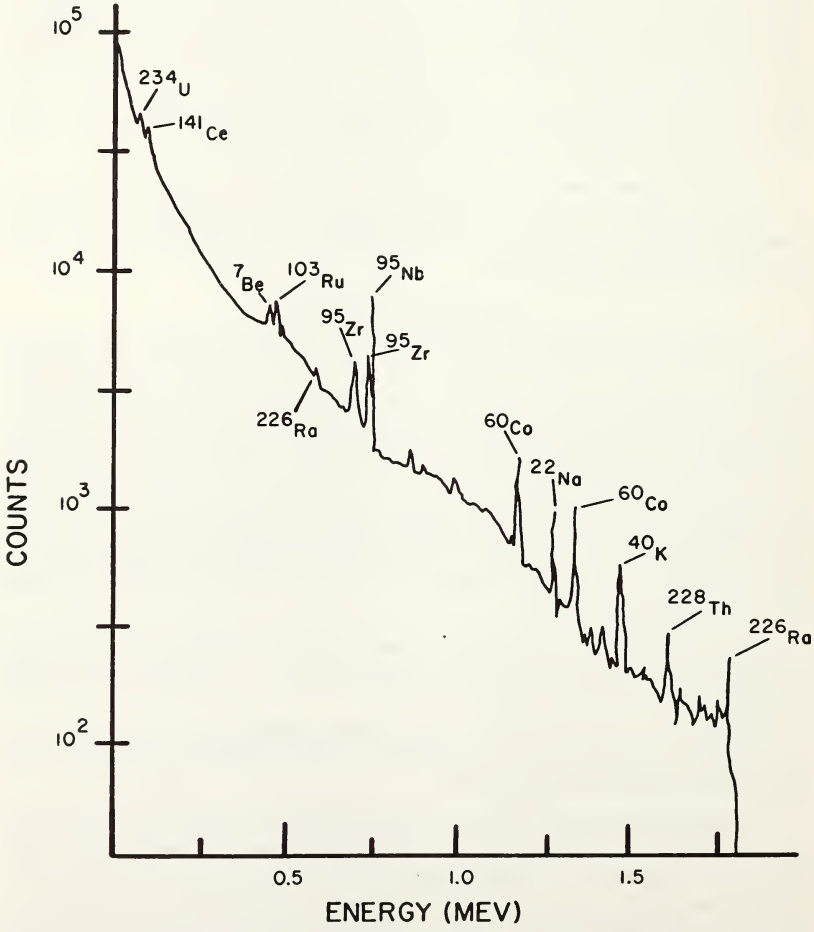

FIGURE 1: *Gamma spectrum of air filter sample from Ball State University*

analyser and transferred to Ball State's Dec System 10 computer for later analysis. The system was calibrated using standard sources of ^{60}Co, ^{22}Na, and ^{137}Cs. A plot of a typical spectrum is shown in Figure 1. Isotopes present in the samples were identified by the energies of their characteristic gamma rays. All gamma-ray peaks were corrected for the efficiency of the lithium-drifted germanium detector. The area under each gamma peak was calculated by the subtraction of a linear background by means of a least squares fit. The activity measured by the areas under the peaks was normalized to the potassium (^{40}K) gamma peak, which was contained in the lab and was constant for all spectra including laboratory background.

Results and Conclusions

^{22}Na, ^{60}Co, and ^{40}K were known to be present in the laboratory background. The ^{7}Be that is present in the spectrum is produced in the atmosphere by cosmic radiation. The isotopes ^{144}Ce, ^{103}Ru, ^{95}Zr and ^{95}Nb are fission fragments which are produced in nuclear fission reactions. Since there are no nuclear power plants in the vicinity of the sampling locations, these fission fragments are most likely due to atmospheric nuclear testing. The age of the fission fragments was calculated from the relative abundances of ^{95}Zr and ^{95}Nb and it was concluded that these isotopes were produced by an atmospheric test by the People's Republic of China on October 16, 1980.

The characteristic activities produced by emissions from coal-fired plants are those of ^{234}U, ^{228}Th, and ^{226}Ra. These long-lived isotopes are trapped in the coal and released as it is burned. These results are presented in Table 2 and quoted errors are due to counting statistics only. The overall uncertainty for error in this study is estimated to be 10%. This includes errors from the geometry of fitting the curve, the efficiency curve of the detector, and the amplifier gain shift in analyzing one of the samples.

The heavy elements ^{226}Ra and ^{228}Thorium were present in the laboratory background and result from the cinder block construction of the building but all samples show an increase in activity due to these isotopes. The ^{234}U activity appears to be a function of distance from the emitting stack. The activity in the Ball State sample which was the closest to the stack was the highest, and the Fairbanks sample, taken almost 2 miles away, showed nothing. The high values for ^{228}Th and ^{226}Ra in the Markleville sample indicate the possibility of their presence in the soil of the region. The larger concentrations of ^{226}Ra at the Ball State plant appear to indicate the need for a pollution control system. The ^{226}Ra and ^{228}Th activities at

TABLE 2 *Heavy Elements*

	^{226}Ra	^{228}TH	^{234}U
BALL STATE	1.582 ± .019	.784 ± .058	.293 ± .005
MARKLEVILLE	1.013 ± .038	.67 ± .016	.075 ± .005
INDIANA UNIVERSITY	.785 ± .036	.330 ± .053	.130 ± .008
FAIRBANKS	.754 ± .037	.517 ± .028	–
LABORATORY BACKGROUND	.466 ± .089	.435 ± .036	–

Indiana University and Fairbanks could not be detected in amounts significantly above background. This can be attributed to their emission control systems which seem to be working.

In general the activities of fission fragments from bomb testing were overwhelmingly greater than those produced by the emissions of coal fired power plants. Therefore, at this time there appears to be no environmental health risk as a result of radionuclide emissions from coal-fired power plants that use appropriate emission control systems. It appears that the atmospheric denotation of nuclear weapons is more of an immediate radiological health hazard than the burning of coal. As we increase our dependence on coal, particularly western coal, close monitoring should be maintained. Further studies of the effects of emission controls on the release of radioactive isotopes to the environment should prove instructive in the design of these systems.

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PLANT TAXONOMY

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ABSTRACTS

Floristic Regions of the World: Doctor Armen Takhtajan's Recent Floristic System. THEODORE J. CROVELLO, Department of Biology, The University of Notre Dame, Notre Dame, Indiana 46556.——In 1978 Takhtajan's book, "Floristic Regions Of The World," appeared in Russian. Motivated partly by a desire to help save the world's plant diversity from extinction,. Takhtajan created a worldwide floristic system, based on his lifelong studies of the plant world. It consists of 6 kingdoms divided into 34 regions, which in turn are divided into almost 150 provinces. Building on Turrill's (1958) term chorion, (a term analogous to taxon, but for biogeographic or floristic units), Takhtajan defines *chorionomy* to include knowledge about choria, and the methods and principles of their study and classification. Takhtajan subscribes to the well-established principles that define each. These include primarily the amount of endemism at species and other taxonomic levels, but also the relationship between absolute size of an area and its level of floristic distinctness. In addition, floristic classification must be kept separate from geobotanical (vegetation) classification. In his Introduction, Takhtajan also addresses the question of whether a worldwide chorionomic system, embracing both animals or plants, is either possible or desirable. Highlights of his floristic system will be presented. Finally, the relationship of such a system (and the data on which it is based) to the approaches of vicariance biogeography and of Crovello's "integrated biogeogeography", will be explored.

Phylogeny, Character Trends, and Distribution Patterns in the Thelypodieae Tribe (Brassicaceae). LARRY A. HAUSER, and THEODORE J. CROVELLO, Department of Biology, The University of Notre Dame, Notre Dame, Indiana 47556.——The phylogenetic and phytogeographic relationships among the taxa of the Thelypodieae tribe were studied. The tribe, as presently delimited, includes eight genera of western North America, one genus of southeastern United States, and one genus of temperate eastern Asia. In addition, several taxa of uncertain relationships were included in the study. The difficulty in understanding these relationships and patterns among taxa, at both the generic and specific levels, is evidenced by the lack of agreement among systematic treatments to date. Boundaries delimiting Thelypodium, Thelypodiopsis, Caulanthus and Streptanthus are especially elusive. Through the analysis of many characters and distribution patterns, insight into these relationships were obtained. Data were collected on over fifty morphological characters and studied for patterns and trends within and among genera. Numerical techniques used include discriminant, principal components, cluster analysis and phylogenetic analyses, such as the Wagner method. These techniques were useful to help elucidate both phylogenetic patterns and relationships as well as of similarities among taxa. Results of this study illustrate many character patterns and trends including reversals and parallelisms.

Phylogenetic hypotheses describing probable species relationship were made for each genus. The distributions of each taxon were also recorded and analyzed among approximately fifty physiographic and floristic regions. Relationships among these taxa, can be better understood in the context of their phytogeographic patterns. Hypotheses involving both vicariance and dispersal are used to explain these distribution patterns as well as other more general floristic patterns.

Was the Type Population of *Quercus ellipsoidalis* E.J. Hill a Hybrid Swarm? RICHARD J. JENSEN, Department of Biology, Saint Mary's College, Notre Dame, Indiana 46556.——*Quercus ellipsoidalis*, the northern pin oak, was first described in 1899. The locality of the type population also contained at least two other taxa closely related to the new species: *Q. palustris* and *Q. velutina*. A third taxon, *Q. coccinea*, may have been present and a fourth, *Q. rubra*, is known to occur in the same general vicinity. Studies of patterns of leaf variation in a number of populations containing one or more of these taxa revealed that individual trees of each taxon formed statistically distinct entities. The analyses were based on eleven variables and were performed by discriminant analysis. Invariably, the discriminant functions generated yielded very high ($\geq$ 90%) levels of assignment of leaves to the trees from which they came. Analysis of several populations known to contain hybrids resulted in significantly lower levels of correct assignment. A similar analysis of E. J. Hill's type specimens of *Q. ellipsoidalis*, in which each specimen was treated as an individual tree, yielded less than 65% correct assignment of leaves to specimens; a statistically significant reduction when compared to 19 (individual species populations and hybrid-containing populations) other analyses. These results suggest that the type specimens may represent collections from a hybrid swarm involving the several taxa present.

Conium maculatum **L. (Poison Hemlock) in Indiana**. PHILIP A. ORPURT, Department of Biology, Manchester College, North Manchester, Indiana 46962.——According to Deam's Flora of Indiana there are 36 species of Umbelliferae (Apiaceae) presently occurring in our state. Of these, 6 species are naturalized. The poison hemlock, *C. maculatum* L. is one of the naturalized species which has become widely distributed throughout the state. The earliest report of its occurrence in Indiana, is that of J. Shenk in 1875 with the notation that it was found in, "fields, rare". In the 24th Annual Report of the Geological Survey (1899) Stanley Coulter notes that *Conium* is, "Chiefly found in the southern counties in waste places; but nowhere abundant". In Deam's Flora (1940) it is shown as occurring in only 14 counties. Deam comments, "Local along roadsides and alluvial banks of streams and locally abundant along the old canal in Huntington, Wabash, and Miami Counties and found, no doubt, farther down the canal". Very probably it now occurs in every county of the state. Furthermore, in some localities and in particular along the route of the old Wabash-Erie Canal from Allen County through Huntington, Wabash, Miami, and Cass Counties it often forms large colonies of plants of considerable density. Its widespread distribution and the extensive formations are particularly disturbing in view of the fact that *Conium* contains two of the most potent toxic alkaloids known (coniine and γ-coniceine). Although the plant is not generally thought to be toxic as a result of contact, it nevertheless represents a real hazard should even small amounts of the plant be consumed by humans or by domesticated animals.

Two New Sedges (*Cyperaceae*) for Indiana. HELENE STARCS, Indianapolis, Indiana.——Field work with the Indiana Natural Heritage Program during 1981 gave two new plant distribution records for the state of Indiana.

1. *Carex socialis* Mohlenbr. and Schwegm. was found while checking some

endangered plant species with botanist James Aldrich in Posey county July 7. The site is located in Halfmoon Woods, just south of Halfmoon Lake, 10 miles SW of Mt. Vernon, and belongs to the lower Wabash Natural Division as stated by A. Lindsey et al. in *Natural Areas in Indiana*. The lowland oak-hickory woods form here the post oak flat on a high alluvial terrace. It has many floral elements of the southern states, as Quercus stellata, Forestiera acuminata, Spigelia marilandica, Hymenocallis occidentalis, Agave virginica, Cocculus carolinus. The new sedge is growing on a slightly elevated area with a coralberry bush (Symphoricarpos orbiculatus). The very loose light green clump is 30 cm diam., the culms about 35 cm high. C. socialis was recently described from southern Illinois.[1] It has been found in four counties there, also in Missouri and Kentucky. It belongs to the subgenus Vignea sect. Bracteosae, in the complex with C. rosea and C. convoluta. From these it differs by very narrow perigynia (0.7-0.8 mm) and by long creeping rhizomes, also the scales are more mucronate. Voucher specimens are deposited at Southern Illinois University Herbarium and Indiana University herbarium.

2. *Scirpus hallii* Gray was found with botanist Kenneth Dritz on a field trip to the Calumet Lake Plain Division, August 9. The small bulrush grows in an excavation in the sandpit south of West Beach, Porter county, with Eleocharis elliptica, E. engelmannii, Hemicarpha micrantha. S. hallii is a rare species, very local also in some other states. It is closely related to S. smithii Fern. and S. purshianus Gray. With S. hallii the achenes are transversally ridged, plano convex, it has no bristles, and the scales are awned. The woucher specimens are deposited at Indiana University herbarium and Morton Arboretum, Illinois.

The Taxonomy of Some Southeastern Sunflowers (*Helianthus* Ser. Microcephali). TIMOTHY STORBECK, Department of Biology, Indiana University, Bloomington, Indiana 47405.——The series Microcephali of the genus *Helianthus* consists of three to five species. These are small-headed, mostly perennial plants found primarily in the southeastern United States. The species that have been included in this series are: *H. microcephalus* (n = 17), *H. glaucophyllus* (n = 17), *H. laeviagatus* (n = 34), *H. smithii* (n = 34) and *H. porteri* (n = 17). While there has been little argument over the taxonomic status of the first three species, the latter two are currently the subject of some disagreement. *Helianthus smithii* is considered by Cronquist to be a tetraploid race of *H. microcephalus*. *Helianthus porteri* was recently placed in this genus by Yates and Heiser. Previously it was included in *Viguiera* and later in the segregate of that genus, *Heliomeris*. *Helianthus porteri* is a species whose affinities are not yet understood.

As part of an ongoing study to test the integrity of the Microcephali, chemical characters including foliar and floral flavonoids and floral carotenoids have been analyzed chromatographically. Morphological characters were also analyzed by various numerical taxonomic procedures. The results of these analyses indicate that *H. smithii*, while closely related to other members of this series, is morphologically and chemically distinct from *H. microcephalus*. Also, *H. porteri* does not appear to be closely related to any other members of the Microcephali. It is suggested that this species be treated as a separate section of *Helianthus* or as a monotypic genus.

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[1] Mohlenbrock, R. H., and J. Schwegman. 1969. A new species of Carex sect. Bracteosae. Brittonia 21 : 77-79.

Limestone Glades of Harrison County, Indiana

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Introduction

Limestone glades are relatively small natural openings in the forest caused by bedrock at or near the surface, usually on steep south or west-facing slopes of seven to twenty degrees. They are dominated by prairie grasses and forbs. This xeric community has not been previously described in studies of Indiana's plant communities (13). In this paper, we will discuss limestone glades recently located in Harrison County, including the methods used to locate, evaluate and describe them. A preliminary species list is presented, including information concerning some very rare floristic elements.

Methods

A systematic search for glades was made in Harrison County during March, 1980 (12). The initial step was an examination of the Agriculture Stabilization and Conservation Service aerial photographs, in conjunction with the 7.5′ United States Geological Survey topographic quadrangle maps, section by section, to select potential glades. Fifty possible glade sites were selected during the map and photo examinations. These were chosen as grassy or brushy openings in the forest on south and west-facing slopes (Figure 1). The county was then flown in a small plane at an altitude of 1000 feet, and the potential sites were examined to determine if they were unnatural, disturbed, or were potentially a natural glade of significance for preservation. Of these fifty, twenty-seven were eliminated.

During the ground survey that followed, four significant glades were identified, and a number of disturbed glades with potential for restoration were also located. The significant glades were determined to be of high natural quality based on a number of factors including: lack of obvious signs of disturbance, relative absence of weedy and alien species, a diversity of native species, and a lack of woody encroachment.

Results

Three of the significant glades were selected for more intensive surveys. During 1981, from April to September, each glade was visited approximately every six weeks to compile a species list. Seventy-two native taxa were identified on these three glades (Table 1). Of particular note is the high number of plants considered rare, endangered or threatened (1,2) in Indiana (Table 2). The axe-shaped St. John's-wort (*Hypericum dolabriforme*) was considered to be extirpated before its discovery in all three glades. It had not been reported for Indiana since Blatchley collected it in 1899 near Wyandotte Cave. The glade heliotrope (*Heliotropium tenellum*), a new state record, was reported by Medley (17) during a visit to one of the glades in August, 1981. This summer annual was subsequently discovered to occur in one other glade. Four other species, slender-stalked gaura (*Gaura filipes*), downy milk pea (*Galactia volunbilis*), flax (*Linum sulcatum*), and heart-leaved

FIGURE 1. *Oblique aerial photo of a Harrison County limestone glade taken in March, 1980. the darker, conical shaped trees in and around the light colored forest opening are eastern red cedar* (Juniperus virginiana).

meadow parsnip (*Zizia aptera*), that are currently listed as state endangered were found to occur in the glades. Two state threatened species, narrowleaf houstonia (*Houstonia nigricans*) and angle-pod (*Gonolobus obliquus*) were also found in the glades.

TABLE 1. *Species occurring in Harrison County, Indiana limestone glades.*[1]

Agave virginica
Allium cernuum
Andropogon gerardii
A. scoparius
Anemone virginiana
Anemonella thalictroides
Asclepias syriaca
A. verticillata
A. variegatum
Aster patens
A. sp.
Carex blanda
C. oligocarpa
C. swanii
Cercis canadensis
Comandra umbellata
Coreopsis tripteris
Danthonia spicata
Dodecatheon meadia
Echinacea purpurea
Eryngium yuccaefolium
Euphorbia corollata
Pelea atropurpurea
Physostegia virginiana
Polygonatum biflorum
Quercus muhlenbergii
Ratibida pinnata
Rhamnus caroliniensis
Rhus aromatica
Rosa carolina
Rudbeckia fulgida
Ruellia caroliniensis (humilis)
Sabatia angularis
Gaura filipes
Gentiana quinquefolia
Gerardia tenuifolia
Gonolobus obliquus
Helliotropium tenellum
Hexalectris spicata
Houstonia angustifolia (nigricans)
Houstonia purpurea
Hypoxis hirsuta
Juniperus virginiana var. *crebra*
Kuhnia eupatorioides
Lespedeza capitata
Liatris aspera
Liatris spicata
Liatris squarrosa
Linum sulcatum
Lithospermum canescens
Lobelia spicata
Lysimachia lanceolata
Melica mutica
Menispermum canadense
Monarda fistulosa
Salvia lyrata
Silphium trifoliatum
Sisyrinchium albidum
Smilax bona-nox
Solidago sp.
Sorghastrum nutans
Sporobolus vaginiflorus
Swertia caroliniensis
Thalictrum revolutum
Viburnum rufidulum
Viola triloba
Zizia aptera

[1] Nomenclature follows Gleason and Cronquist, 1963.

TABLE 2. *Rare, threatened and endangered species in the Harrison County Limestone glades and their relative sdtatus, including protectedness, in Indiana.*

Species	Status	Number of Occurrences in Glades	Total Extant Sites	Protected[1] Sites
Galactia volubilis	Endangered	3	4	0
Gaura filipes	Endangered	3	5	1
Gonolobus obliquus	Threatened	2	4	0
Heliotropium tenellum	Endangered[2]	2	2	0
Houstonia migricans	Threatened	3	7	0
Hypericum dolabriforme	Endangered	3	4	1
Liatris squarrosa	Rare	1	4	1
Linum sulcatum	Endangered	2	4	0
Melica mutica	Rare	3	12	0
Zizia aptera	Endangered	3	5	1

[1] Occurrences of viable populations on State Nature Preserves.

[2] Proposed status.

Discussion

The glades of Harrison County are a relic component of the barrens or prairies of southern Indiana that in presettlement times covered 33,250 hectares in Washington and Harrison Counties (15). These prairies were *primarily restricted* to the Mitchell Plain Physiographic Province (18). This province extends into Kentucky, where limestone glades also occur (4,5).

Five limestone glades have previously been reported from this physiographically similar area in Kentucky. The Baskins listed 148 taxa, 25 of which were alien, from five glades within the barrens region of Kentucky. This high number of taxa reflects quite a bit of disturbance from grazing and subsequent invasion of many weedy species (5). The number of taxa from the Harrison County glades that were surveyed, which were relatively undisturbed natural areas, contained 72 taxa. Of particular importance is the lack of weedy and alien species, attesting to the relative absence of past disturbance.

No accounts have been written about the plant ecology or other unique elements of the southern Indiana glades (13), but published accounts of limestone glades in the adjoining states of Ohio (14,21), Kentucky (4,5) and Illinois (16) have been written. Little, besides historical accounts, has been written about the once more extensive "barrens" that may no longer exist in Indiana. Although these noteworthy communities are an outlying component of the mid-western prairies within the eastern deciduous forest region, it was not recognized by E. N. Transeau (20). This may be because he relied on Gordon's vegetation map of Indiana (11). Gordon may have overlooked these areas because the English-speaking settlers to the area used the term "Barrens" to describe these prairie areas since they associated the absence of trees with non-productive soils or barren lands. However, it should be known that Deam (8) was aware that presettlement barrens had existed in Indiana through communications with Gleason (9), and from the collections and notes of Dr. A. Clapp at DePauw University and C. W. Short's collections of *Aconitum uncinatum* in 1840 and 1842 from the "Barrens near Corydon".

The prairie element in the Harrison County limestone glades appears to be well represented. Thirty-eight species that occurred in the limestone glades have major distributions in the Great Plains (3). Similarly, thirty-three species are found in prairie or savanna habitats in northwest Indiana (19). Only a few of the Harrison County glade species are frequently found on cedar glades in the southeastern United States. These include *Andropogon scoparius*, *Hypericum dolabriforme* and *Oxalis violacea* (6). Many of the remaining glade species are also frequently encountered in dry, open woodlands and on exposed cliffs in the central Ohio River Counties of Indiana. These appear to have originated as elements of the eastern deciduous forest. This may be related to the prairie grass formation of the Midwest described by Gleason (9) to have occurred near the close of the xerothermic period. At this time, many western prairie species were unable to withstand large increases in moisture and were replaced by grasses and forbs, a more mesic, eastern derivation. Three of the most important Illinois prairie grasses, *Andropogon gerardi*, *A. scoparius*, and *Sorghastrum nutans*, which also occur in the Harrison County glades, were of eastern origin (9).

The remnant glades of Harrison County have resisted the encroachment of woody vegetation. their persistance involves a complex interplay of factors including thin soils, a southerly aspect, seven to twenty degree slopes, xeric conditions, and fire. Undoubtedly it has been Western man's post-settlement control and suppression of fire (21), as well as agricultural activities (7), that has been one of the

primary factors influencing the elimination or replacement of both glades and barrens by woody vegetation.

Although the glades are saturated with water during late fall, winter and spring, due to their southerly exposure and associated climatic conditions, they are very xerix during the summer months. This annual prolonged xeric period in combination with very thin or nearly lacking soil probably puts a severe physiological stress on woody invaders and correspondingly results in a very high mortality rate among wood species. Even so, the lack of fire has taken its toll on the glades' integrity and they are in danger of being squeezed out of existence if fire does not once again become an integral part of the maintenance of these unique areas. Aerial photographs document the continuing shrinkage of these glades, as they were nearly double their present size in the 1940s.

None of the glades are presently protected and managed as state natural areas. They and their rare floristic elements face an uncertain future. Fortunately, efforts towards their protection and management are being taken. Owners of two of the glades have agreed to protect their glades voluntarily through the Indiana Natural Areas Registry, a cooperative program between the Department of Natural Resources and The Nature Conservancy, supported by a grant from the Lilly Endowment. Another glade will be leased for preservation purposes. Future inventory efforts to locate, evaluate and study other similar and different types of glades in Indiana are also much needed.

Acknowledgments

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Vegetation Survey of Chauncey Marsh, Lawrence County, Illinois

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Introduction

Chauncey Marsh is an extensive wetlands in northwestern Lawrence County (Sec. 30 T5N R12W; Sec 25 and 36 T5N R13W) about four miles east of Chauncey, Illinois. This marsh, located on an old ox-bow of the Embarrass River, is the largest marsh remaining in the Illinois portion of the Wabash River basin. Though subjected to some disturbances, including drainage attempts, the marsh still contains a wide variety of plant and animal life, some of which has all but disappeared from the state. As a result the Illinois Department of Conservation has purchased most of the marsh and some of the surrounding floodplain forest. Present plans are to dedicate this area as a nature preserve.

During the present study a vegetation survey was undertaken in the three major vegetation zones of the marsh. Also, a list of the vascular plant species found in the marsh was obtained by making numerous trips to the area during the past four years.

Materials and Methods

The three major vegetation zones in the marsh were samples using plot $1/8m^2$ in size. Using a random numbers table 80 circular plots were randomly located along compass lines through each zone. Each stem found was considered a separate individual (with grasses and grass-like plants each cluster of leaves was considered a stem), and the total number of individuals of each species in each plot was recorded. From these data the density (stems per m^2), frequency, relative density, relative frequency, and importance value (IV) for each species was then determined.The relative values were calculated using the following formulas.

$$\text{Relative Density} = \frac{\text{Total individuals of a species}}{\text{Total individuals of all species}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Total plots of occurrence of a species}}{\text{Total plots of occurrence of all species}} \times 100$$

$$\text{Importance Value} = \text{Relative Density} + \text{Relative Frequency}$$

The nomenclature used follows Mohlenbrock (1975).

Results and Discussion

Chauncey Marsh is located in the Bottomlands Section of the Wabash Border Division (Schwegman, 1973). This section encompasses the bottomland forests, sloughs, marshes, and ox-bow lakes in the floodplains of the Wabash River, the Ohio River, and their major tributaries. The predominant vegetation of this section consists of bottomland forests, though wet prairies and marshes are sometimes associated with the sloughs and meander scars.

Due to the large size of the marsh (nearly 400 acres) only the least disturbed section was studied. The area studied is located on state owned land in the eastern part of the marsh (SW¼ Sec 30 T5N R12W). The vegtation in this area is relatively uniform, and can be divided into three fairly distinct zones. These zones, which

probably developed as a result of moisture gradients and shading, are discussed below.

Scirpus/Hibiscus Zone: This zone occurs in the wetter, open parts of the marsh. Standing water is common during spring and early summer, and some shallow depressions contain water year around. *Scirpus fluviatilis* (river bulrush) and *Hibiscus militaris* (halberd-leaved rose mallow) are the dominant taxa in this zone (Table 1), averaging 61 stems per m^2, and having a combined importance value of 142.4. Other common associated species include *Carex hyalinolepis*, *Lippia lanceolate*, *Acorus calamus*, and *Scirpus acutus*. Though 19 taxa were found in the plots, most have extremely low importance values (Table 1). Of these minor taxa,

TABLE 1. *Density, frequency, and relative values of the species in the Scirpus/Hibiscus zone of Chauncey Marsh, Lawrence County, Illinois.*

Species	Den. m^2	Freq. %	Rel. Den.	Rel. Freq.	I.V.
Scirpus fluviatilis (Torr.) Gray.	39.8	97.5	49.6	38.5	88.1
Hibiscus militaris Cav.	21.4	70.0	26.6	27.7	54.3
Carex hyalinolepis Steud.	4.1	13.8	5.1	5.4	10.5
Lippia lanceolata Michx.	2.2	13.8	2.7	5.4	8.1
Acorus calamus L.	3.4	5.0	4.2	2.0	6.2
Scirpus acutus Muhl.	2.7	5.0	3.4	2.0	5.4
Myriophyllum heterophyllum Michx.	.7	8.8	1.0	3.5	4.5
Rumex verticillatus L.	.9	7.5	1.1	3.0	4.1
Polygonum coccineum Muhl.	.6	7.5	.9	3.0	3.9
Ludwigia polycarpa Short & Peter.	1.3	3.8	1.6	1.5	3.1
Peltandra virginica (L.) Kunth.	.5	5.0	.6	2.0	2.6
Proserpinaca palustris L.	1.3	1.3	1.6	.5	2.1
Asclepias incarnata L.	.3	2.5	.3	1.0	1.3
Sium suave Walt.	.2	2.5	.2	1.0	1.2
Cephalanthus occidentalis L.	.2	2.5	.2	1.0	1.2
Boltonia asteroides (L.) L'Her.	.2	2.5	.2	1.0	1.2
Iris shrevei Small.	.4	1.3	.5	.5	1.0
Saururus cernuus L.	.1	1.3	.1	.5	.6
Sagittaria brevirostra Mack. & Bush	.1	1.3	.1	.5	.6
Totals	80.4		100.0	100.0	200.0

most are wet area species that would be expected in this habitat. Of this group *Cephalanthus occidentalis* is the only woody species present, while *Myriophyllum heterophyllum* and *Proserpinaca palustris* occur only in standing water.

Spartina/Carex Zone: This zone occurs in the drier, open parts of the marsh, and should probably be classified as wet prairie. This zone is rarely flooded, and is relatively dry most of the year. *Spartina pectinata*, *Carex hyalinolepis*, and *Carex stricta* dominate this zone, account for nearly 150 of the 157 per m^2, and have a combined importance value of 176.8 (Table 2). Only 8 other taxa were found in the plots of this zone, most of which also occurred in the *Scirpus/Hibiscus* zone.

Salix/Carex Zone: This zone is dominated by an overstory of various shrubs and trees. *Salix interior* is the dominant woody plant present, though other woody species are also common. These include *Salix nigra*, *Acer saccharinum*, *Fraxinus pennsylvanica* var. *subintegerrima*, *Populus heterophylla*, *Amorpha fruticosa*, and *Morus rubra*. The herbaceous layer is more diverse here than in the other zones

TABLE 2. *Density, frequency, and relative values of the species in the Spartina/Carex zone of Chauncey Marsh, Lawrence County, Illinois.*

Species	Den. m^2	Freq. %	Rel. Den.	Rel. Freq.	I.V.
Spartina pectinata Link.	76.9	83.8	48.8	31.3	80.1
Carex hyalinolepis Steud.	39.7	73.8	25.2	27.4	52.6
Carex stricta Lam.	32.7	62.5	20.8	23.3	44.1
Polygonum coccineum Muhl.	3.4	27.5	2.2	10.2	12.4
Scirpus acutus Muhl.	2.8	5.0	1.7	1.9	3.6
Cephalanthus occidentalis L.	.4	5.0	.3	1.9	2.2
Asclepias incarnata L.	.6	3.8	.4	1.4	1.8
Apocynum cannabinum L.	.4	3.8	.3	1.4	1.7
Lippia lanceolata Michx.	.1	1.3	.1	.4	.5
Rumex verticillatus L.	.1	1.3	.1	.4	.5
Boltonia asteroides (L.) L'Her.	.1	1.3	.1	.4	.5
Totals	157.2		100.0	100.0	200.0

studied, with 24 taxa found in the plots. Of these species, *Carex stricta* is the most important, accounting for 39.1 stem per m^2 and having an importance value of 96.2 (Table 3). The other taxa found in this zone have extremely low densities and importance values.

A total of 165 taxa of vascular plants were found in and at the edge of Chauncey Marsh. These taxa are listed below with their collecting information. In

TABLE 3. *Density, frequency, and relative values of the herbaceous species in the Salix/Carex zone of Chauncey Marsh, Lawrence County, Illinois.*

Species	Den. m^2	Freq. %	Rel. Den.	Rel. Freq.	I.V.
Carex stricta Lam.	39.1	85.0	59.2	37.0	96.2
Carex muskingumensis Schwein.	4.1	21.3	6.2	9.2	15.4
Aster ontarionis Wieg.	2.8	15.0	4.2	6.5	10.7
Boehmeria cylindrica (L.) Sw.	2.8	12.5	4.2	5.4	9.6
Apios americana Medic.	1.5	16.3	2.3	7.1	9.4
Elymus virginicus L.	3.1	10.0	4.7	4.3	9.0
Pilea pumila (L.) Gray	2.9	7.5	4.4	3.3	7.7
Polygonum coccineum Muhl.	1.2	12.5	1.8	5.4	7.2
Ambrosia trifida L.	1.0	11.3	1.5	4.9	6.4
Scutellaria lateriflora L.	1.7	5.0	2.6	2.2	4.8
Saururus cernuus L.	1.3	3.8	2.0	1.6	3.6
Lysimachia ciliata L.	1.3	3.8	2.0	1.6	3.6
Lippia lanceolata Michx.	.6	5.0	.9	2.2	3.1
Sium suave Walt.	.8	2.5	1.2	1.0	2.2
Leersia virginica Willd.	.3	3.8	.5	1.6	2.1
Lycopus rubellus Moench.	.3	3.8	.5	1.6	2.1
Hibiscus lasiocarpos Cav.	.3	2.5	.5	1.0	1.5
Rumex altissimus Wood.	.3	1.3	.5	.6	1.1
Iris shrevei Small.	.2	1.3	.3	.6	.9
Galium obtusum Bigel.	.1	1.3	.1	.6	.7
Lobelia cardinalis L.	.1	1.3	.1	.6	.7
Bidens aristosa L.	.1	1.3	.1	.6	.7
Asclepias incarnata L.	.1	1.3	.1	.6	.7
Peltandra virginica (L.) Kunth.	.1	1.3	.1	.5	.6
Totals	66.1		100.0	100.0	200.0

this list the first number after the name is the authors collecting number, while the other numbers refer to the area or areas in which the species was found (1. *Scirpus/Hibiscus* Zone; 2. *Spartina/Carex* Zone; 3. *Salix/Carex* Zone; 4. Disturbed, open area; and 5. Edge of marsh in floodplain forest).

Alismaceae
Sagittaria brevirostra Mack. & Bush. 20820; 1,3,4.

Araceae
Acorus calamus L. Not collected; 1.
Peltandra virginica (L.) Kunth. 15719; 1,3,4,5.

Commelinaceae
Commelina virginica L. 17369; 4.
Tradescantia ohiensis Raf. 17239; 4.

Cyperaceae
Carex cruscorvi Shuttlew. 17314; 5.
Carex davisii Schw. & Torr. 15710; 5.
Carex grayi Carey. 15708; 3.5.
Carex hyalinolepis Steud. 17266; 1,2.
Carex lupulina Muhl. 17315; 4,5.
Carex muskingumensis Schw. 17259; 3.5.
Carex squarrosa L. 17326; 5.
Carex stricta Lam. 17262; 2,3.
Carex vulpinoidea Michx. 17261; 4.
Cyperus acuminatus Torr. & Hook. 13473; 4.
Cyperus erythrorhizos Muhl. 13486; 4.
Cyperus esculentus L. 20788; 4.
Cyperus ferruginescens Boeckl. 20774; 4.
Cyperus strigosus L. 20778; 4.
Eleocharis acicularis (L.) R. & S. 15723; 4.
Eleocharis obtusa (Willd.) Schult. 17305; 4.
Scirpus acutus Muhl. 17304; 1,2.
Scirpus atrovirens Willd. 17306; 4.
Scirpus cyperinus (L.) Kunth. 20816; 2.
Scirpus fluviatilis (Torr.) Gray. 15724; 1.
Scirpus heterochaetus Chase. 13070; 4.

Dioscoreaceae
Dioscorea villosa L. 17334; 3,5.

Iridaceae
Iris shrevei Small. 17248; 1,3.

Juncaceae
Juncus acuminatus Michx. 17256; 2,4.
Juncus tenuis Willd. 17307; 4.

Lemnaceae
Spirodela polyrhiza (L.) Schleid. 17395; 1.

Poaceae
Alopecurus carolinianus Walt. 17229; 4.
Calamagrostis canadensis (Michx.) Beauv. 17255; 2.
Chasmanthium latifolium (Michx.) Yates. 17329; 5.
Cinna arundinacea L. 13420; 5.
Digitaria ischaemum (Schreb.) Muhl. 13442; 4.

Digitaria sanguinalis (L.) Scop. 17370; 4.
Echinochloa crus-galli (L.) Beauv. 20785; 4.
Eleusine indica (L.) Gaertn. 17375; 4.
Elymus virginicus L. 13418; 3,5.
Eragrostis cilianensis (All.) Mosher. 17373; 4.
Eragrostis hyponides (Lam.) BSP. 17383; 4.
Eragrostis pectinacea (Michx.) Nees. 13429; 4.
Leersia lenticularis Michx. 17330; 2.
Leersia virginica Willd. 13412; 3,5.
Panicum capillare L. 13461; 4.
Panicum dichotomiflorum Michx. 13460; 4.
Panicum rigidulum Bosc. 13422; 4.
Panicum virgatum L. 20808; 2.
Setaria faberi Herrm. 17357; 4.
Setaria lutescens (Weigel) Hubb. 20765; 4.
Spartina pectinta Link. Not collected; 2.
Sporobolus vaginiflorus (Torr.) Wood. 17374; 4.

Acanthaceae
Ruellia strepens L. 15720; 4.

Amaranthaceae
Amaranthus hybridus L. 13477; 4.

Apocynaceae
Amsonia tabernaemontana Walt. 15702; 2.
Apocynum cannabinum L. 17228; 2,3,4.

Asclepiadaceae
Asclepias incarnata L. 13456; 1,2,3,4.
Asclepias perennis Walt. 13409; 5.
Cynanchum laeve (Michx.) Pers. 13478; 4.

Campanulaceae
Lobelia cardinalis L. 13431; 3,4,5.
Lobelia siphilitica L. 13430; 3,4.

Caprifoliaceae
Sambucus canadensis L. 17230; 3,4,5.

Compositae
Ambrosia artemisiifolia L. 20790; 4.
Ambrosia trifida L. 20769; 3,4.
Aster ontarionis Wieg. 20787; 3,5.
Aster simplex Willd. 17437; 5.
Bidens aristosa L. 13476; 3,4.
Bidens comosa (Gray) Wieg. 17366; 4.
Bidens frondosa L. 20775; 4.
Bidens vulgata Greene. 13457; 4.
Boltonia asteroides (L.) L'Her. 13391; 1,2,4.
Eclipta alba (L.) Hassk. 20773; 4.
Erechtites hieracifolia (L.) Raf. 20794; 3,5.
Eupatorium coelestinum L. 13419; 3,5.
Eupatorium serotinum Michx. 17322; 2,3.
Helenium autummale L. 13427; 3,4.
Senecio glabellus Poir. 17241; 4.

Silphium perfoliatum L. 13448; 2,4,5.
Vernonia gigantea (Walt.) Trel. 13471; 2,4.
Vernonia fasciculata Michx. 13482; 2,3.
Xanthium strumarium L. 13451; 4.

Convolvulaceae
Cuscuta gronovii Willd. 17324; 2,4.
Ipomoea hederacea Jacq. 17379; 4.
Ipomoea lacunosa L. 20786; 4.
Ipomoea pandurata (L.) G. F. W. Mey. 13463; 4.

Cornaceae
Cornus obliqua Raf. 17244; 4.
Cornus racemosa Lam. 13465; 4.

Cruciferae
Armoracia aquatica (A. Eaton) Wieg. 13067; 1.
Iodanthus pinnatifidus (Michx.) Steud. 15711; 5.
Rorippa islandica (Oeder) Borbas. 15722; 4.
Rorippa sessiliflora (Nutt.) Hitchc. 17246; 1.

Cucurbitaceae
Sicyos angulatus L. 13414; 5.

Euphorbiaceae
Acalypha gracilens Gray. 17352; 4.
Acalypha rhomboidea Raf. 13469; 4.
Chamaesyce maculata (L.) Small. 17351; 4.
Chamaesyce supina (Raf.) Moldenke. 17350; 4.
Phyllanthus caroliniensis Walt. 13467; 4.

Haloragidaceae
Myriophyllum heterophyllum Michx. 17316; 1.
Proserpinaca palustris L. 15716; 1.

Hypericaceae
Hypericum mutilum L. 13454; 4.
Hypericum sphaerocarpum Michx. 17311; 2.

Labiatae
Lycopus americanus Muhl. 17394; 2,4.
Lycopus rebellus Moench. 20812; 3.
Mentha arvensis L. 20762; 3,4.
Physostegia speciosa Sweet. 13415; 5.
Scutellaria lateriflora L. 13424; 2,3,4.
Teucrium canadense L. 17337; 2,3,4.

Leguminosae
Amorpha fruticosa L. 13453; 3.
Apios americana Medic. 17393; 3.
Cassia marilandica L. 13428; 3,4.
Trifolium hybridum L. 20767; 4.

Lythraceae
Ammannia coccinea Rottb. 13440; 4.
Lythrum alatum Pursh. 17308; 4.

Malvaceae
Hibiscus lasiocarpos Cav. 13397; 1,3,4.

Hibiscus militaris Cav. 13447; 1,4.
Sida spinosa L. 13450; 4.

Moraceae
Morus rubra L. 17336; 3,5.

Oleaceae
Fraxinus pennsylvanica Marsh. 20793; 3.

Onagraceae
Ludwigia alternifolia L. 13484; 3,4.
Ludwigia palustris (L.) Ell. 13434; 4.
Ludwigia polycarpa Short. & Peter. 20802; 1.
Oenothera pilosella Raf. 13079; 2,4.

Oxalidaceae
Oxalis stricta L. 13410; 4.

Polygonaceae
Polygonum aviculare L. 17385; 4.
Polygonum coccineum Muhl. 13393; 1,2,3,4.
Polygonum erectum L. 13445; 4.
Polygonum hydropiper L. 13458; 4.
Polygonum hydropiperoides Michx. 17342; 4.
Polygonum lapathifolium L. 17359; 4.
Polygonum pensylvanicum L. 13394; 4.
Polygonum punctatum Ell. 20771; 4.
Polygonum scandens L. 13481; 4.
Rumex altissimus Wood. 17253; 3,4.
Rumex verticillatus L. 17250; 1,2.

Primulaceae
Lysimachia ciliata L. 20797; 2,3,4.
Samolus parviflorus L. 13071; 4.

Ranunculaceae
Anemone canadensis L. 15703; 4.
Clematis pitcheri Torr. & Gray. 13468; 3,4.

Rosaceae
Potentilla norvegica L. 13455; 4.
Rubus allegheniensis Porter. 17242; 3,4.
Spiraea alba DuRoi. 17312; 2.

Rubiaceae
Cephalanthus occidentalis L. 13401; 1,2.
Galium obtusum Bigel. 17243; 3,4.
Spermacoce glabra Michx. 17433; 4.

Salicaceae
Populus heterophylla L. 13452; 3,5.
Salix interior Rowlee. 17240; 3,4.
Salix nigra Marsh. 17252; 3,5.

Saxifragaceae
Penthorum sedoides L. 13435; 3,4,5.

Saururaceae
Saurusus cernuus L. 13399; 1,3,4,5.

Scrophulariaceae
Chelone obliqua L. 13416; 5.
Conobea multifida (Michx.) Benth. 17377; 4.
Gratiola neglecta Torr. 15712; 4.
Gratiola virginiana L. 15705; 4.
Lindernia anagallidea (Michx.) Pennell. 13472; 4.
Mimulus alatus Ait. 17343; 3,4.
Mimulus ringens L. 13395; 4.

Solanaceae
Physalis subglabrata Mack. & Bush. 13406; 4.

Umbelliferae
Sium suave Walt. 20811; 1,3,5.

Urticaceae
Boehmeria cylindrica (L.) Sw. 13398; 3,5.
Pilea pumila (L.) Gray. 13432; 3,4,5.

Verbenaceae
Lippia lanceolata Michx. 13072; 1,2,3,4.

Violaceae
Viola pratincola Greene. 20760; 3,4,5.

Vitaceae
Ampelopsis cordata Michx. 13446; 4.
Vitis cinerea Engelm. 17392; 4,5.

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New Records of Plant Species for Posey County, Indiana

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Introduction

Floristic studies were conducted in a study area located in Posey County, in southwestern Indiana. Quantitative and qualitative sampling of this study area was conducted over a 2-year period and included seasonal surveys. Five distinct vegetation types were found to occur within the study area. The Indiana Academy of Science 1981 computer species list for Posey County was utilized for a determination of the previous plant species records.

Study Area

The vegetation study area is located in Posey County, Indiana which comprises the southwestern corner of the state. The study area in Posey County is found within the Hill section of the Western Mesophytic Forest Region (1). The site lies within the Highland Rim section of the Interior Low Plateau physiographic province (14). The study site occupies approximately 681 acres (275.6 hectares) and is directly north of the Ohio River. Located in T7S, R12W, Sec. 13 and 24, the eastern edge of the study area borders the Posey-Vanderburg County line. The town of West Franklin is located approximately one-half mile southeast of the study site. The relief on site varies from an elevation of 340 feet (103.6 meters) to 467 feet (142.3 meters) above mean sea level (msl). A broad gently sloping floodplain gives way to a gradual rolling upland area of narrow ridges and moderate to steep-sided valleys. The surficial soils of the study area consist of three major types: bottomland soils, slope soils, and upland soils (15). Most of these soils consist of silt loams with varying degrees of erodability related to vegetation cover and slope gradient. For purposes of floristic investigation, the concept of the representative habitat (vegetation type) was employed. A total of five representative vegetation types were delineated and studied in detail. The five representative vegetation types included oldfield, pastureland, disturbed land (riparian), ponds, and woods types.

Methods and Materials

All strata of vegetation within the five major vegetation types were surveyed. Ground cover vegetation was sampled utilizing the microplot-quadrat method (12, 5, 16). The method utilizes uniform one-tenth meter, spaced sampling plots and provides frequency, density, and dominance information. In addition, several one-tenth acre circular plots were utilized in the oldfield, pasture, and woods vegetation types. Increment core analysis was used in wooded study locations to document successional development.

Overstory and understory vegetation strata were sampled utilizing the point-centered quarter (PCQ) method (4, 16, 17). the PCQ method provides quantitative information about relative density, frequency, dominance, species frequency, and total basal area. In addition to the PCQ sampling method, qualitative inventory sampling was performed for each sampling and survey. All of these methods coupled with seasonal observations and records taken of the pond provided input to a detailed analysis of the study area.

Preliminary vegetation maps of the study site were prepared from available aerial photography. Both black and white and false-color infrared aerial photographs were taken of the site for detailed analysis and to provide a generalized picture of the major floristic types investigated and their locations within the site.

The oldfield sampling location was situated in the northeastern portion of the study site in an area of gently sloping land. Soils within this study site included primarily slope soils covered by ½ to 1½ inches (1.3 to 3.8 centimeters) of organic debris.

The pastureland sampling location was located in the northern portion of the site in an area dissected by an intermittent drainageway. Pastureland soils were similar to the soils of the oldfield area and were covered by ¼ to ½ inch (0.6 to 1.3 centimeters) of organic debris. Previous mowing or spraying pressure was evident in non-wooded areas of the pastureland location.

The disturbed land sampling area was located in the central portion of the site and consisted of pastureland, woods, and oldfield vegetation types which are cleared of vegetation 1 to 2 years prior to the survey program for site development purposes. The vegetation of the disturbed land represented a wide variety of "pioneer" species which included dominant components of the othe other predominant vegetation types of the site. The pond sampling area was located in the northeast-central portion of the site and included two pond areas fed by an intermittent drainageway. Notable plant zonation was found around each pond location.

The remaining vegetation type consisted of woods. Within the cover type, woods was subdivided into mixed hardwoods and beech woods. The mixed hardwoods extended in an easterly direction from the western edge of the site covering slopes, valleys, and ridges within the forest. The beech woods was most commonly observed on northfacing slopes within the woodlands.

Taxonomic determinations for various field specimens were made based on comparison and validation with voucher specimens on file at the Indiana University Herbarium in Bloomington, and the University of Cincinnati Herbarium in Cincinnati.

Results and Discussion

The Indiana Academy of Science computerized plant species list for Posey County, Indiana indicates a recorded flora of 800 species (11). This computerized listing includes both native and introduced plants which have been previously recorded from the county. In this specific vegetation investigation of Posey County, a total of 272 plant species, representative of 196 genera and 89 families were recorded. Careful comparison of the Posey County field species list with the Indiana Academy of Science computerized listing indicated that of the 272 plant species recorded, a total of 207 records represented species previously identified from Posey County. A total of 65 new plant species records were uncovered as the result of this field investigation (Table 1). The identification of 65 new plant species in Posey County should not be construed as a recent plant migration into Posey County. Rather, comparison of the field species list with surrounding county species lists indicates that several of the species are commonly found in adjacent counties and perhaps were not uncovered (although present) during the prior floristic investigations in Posey County. This vegetation survey information collected for Posey County should provide an update and addition to both the local and regional flora of southwestern Indiana.

TABLE 1. *New Plant Species of Posey County Study Area*

Scientific Name Common Name	Sampling Area 1 (Oldfield Vegetation Type)	Sampling Area 2 (Pastureland Vegetation Type)	Sampling Area 3 (Disturbed Land Vegetation Type)	Sampling Area 4 (Ponds Vegetation Type)	Sampling Area 5 (Woods Vegetation Type)
Agrimonia parviflora Ait. Smallflower agrimony	C, c	C	D	D	–
Albizzia julibrissin Durazz. Albizzia	–	–	–	D	–
Alisma subordatum Raf. Water plantain	–	–	–	D	–
Allium canadense L. Meadow garlic	C	C, D	D	–	C
Allium vineale L. Crow garlic	c	D	D	–	–
Anacharis canadensis (Michx.) Planch. Canada waterweed	–	–	–	–	D
Arctium minus (Hill.) Bernh. Common burdock	–	–	–	–	C
Arisaema triphyllum (L.) Schott. Jack-in-the-pulpit	–	–	–	–	D
Artemisia absinthium L. Common wormwood	–	C	–	–	–
Asclepias verticillata L. Horsetail milkweed	c	–	–	–	–
Ascyrum hypericoides L. var. *multicaule* (Michx.) Fern. St. Andrew's cross	–	–	–	–	D
Asimina triloba (L.) Dunal. Papaw	–	–	–	–	b, c, D

Brassica nigra (L.) Koch. Black mustard	–	C, D	–	–	–
Carya glabra (Mill.) Sweet Pignut hickory	B	–	–	–	A, B, D
Cassia nictitans L. Small-flower sensitive plant	–	–	D	D	–
Cirsium discolor (Muhl.) Spreng. Field thistle	C, c	C	D	D	–
Cynoglossum officinale L. Common houndstongue	–	–	–	D	D
Daucus carota L. Common carrot	C, c	C, D	D	D	C
Dicentra canadensis (Goldie) Walp. Squirrelcorn	–	–	–	–	D
Dipsacus sylvestris Huds. Common teasel	–	C	D	–	–
Dryopteris marginalis (L.) A. Gray Leather woodfern	–	–	–	–	D
Epilobium coloratum Muhl. Willowherb	–	–	–	D	–
Equisetum laevigatum A. Br. Smooth scouring rush	–	–	D	–	–
Erigenia bulbosa (Michx.) Nutt. Harbinger-of-spring	–	–	–	–	D
Erythronium albidum Nutt. White trout lily	–	–	–	–	D
Eupatorium purpureum L. Green-stem Joe-pye-weed	–	–	D	–	–
Euonymus atropurpureus Jacq. Wahoo	–	–	–	–	D
Festuca elatior L. Meadow fescue	C, c	C	D	D	–

TABLE 1.—Continued

Scientific Name Common Name	Sampling Area 1 (Oldfield Vegetation Type)	Sampling Area 2 (Pastureland Vegetation Type)	Sampling Area 3 (Disturbed Land Vegetation Type)	Sampling Area 4 (Ponds Vegetation Type)	Sampling Area 5 (Woods Vegetation Type)
Fragaria virginiana Duchesne. Virginia strawberry	–	–	–	–	D
Hydrophyllum canadense L. Broadleaf waterleaf	–	–	–	–	D
Hydrophyllum macrophyllum Nutt. Largeleaf waterleaf	–	–	–	–	D
Ipomoea purpurea Roth. Common morning-glory	–	C, D	–	–	C
Juncus effusus L. var. *solutus* Fern and Wieg. Soft rush	–	–	–	D	–
Juncus macer S.F. Gray Rush	–	–	–	D	–
Juniperus virginiana L. var. *crebra* Fernand & Grissom Eastern red cedar	B	–	–	–	D
Lactuca scariola L. Prickly lettuce	–	D	D	–	–
Mentha arvensis L. Field mint	–	C	D	–	–
Mitella diphylla L. Bishopscap	–	–	–	–	c, D
Nelumbo pentapetala (Walt.) Fern American lotus	–	–	–	D	–
Onoclea sensibilis L. Sensitive fern	–	–	–	D	–

Panax quinquefolium L. American ginseng	–	–	–	–	D
Phragmites communis Trin. Common reed	–	–	D	–	–
Plantago lanceolata L. Buckhorn	C, e	C, D	C, D	D	–
Poa pratenis L. Kentucky bluegrass	C, e	C	C	C	C
Potentilla monspeliensis L. Rough cinquefoil	D	–	–	–	–
Quercus borealis Michx. var. *maxima* (Marsh) Ashe Red oak	–	–	–	–	A, B, D
Quercus prinus L. Swamp chestnut oak	–	B	–	–	–
Rhus typhina L. Staghorn sumac	B, D	B	D	B, D	–
Rosa multiflora Thunb. Japanese rose	D, e	D	–	B, C, D	C
Rubus flagellaris Willd. Northern dewberry	C	–	–	–	–
Rubus occidentalis L. Common blackcap raspberry	C, e	C, D	D	B, C, D	D
Sanquinaria canadensis L. Bloodroot	–	–	–	–	C, D
Sassafras albidum (Nutt.) Nees. Sassafras	B	–	–	D	A, B
Setaria lutescens (Weigel) F.T. Hubb. Yellow foxtail	C	D	–	–	–
Solidago canadensis L. Canada goldenrod	C, e	D	D	D	–
Taraxacum officinale Weber Common dandelion	C	D	–	–	–

TABLE 1.—Continued

Scientific Name Common Name	Sampling Area 1 (Oldfield Vegetation Type)	Sampling Area 2 (Pastureland Vegetation Type)	Sampling Area 3 (Disturbed Land Vegetation Type)	Sampling Area 4 (Ponds Vegetation Type)	Sampling Area 5 (Woods Vegetation Type)
Trifolium pratense L. Red clover	C	C, D	D	D	–
Trifolium repens L. White clover	c	–	D	–	–
Trillium sessile L. Sessile-flower trillium	–	–	–	–	D
Ulmus rubra Muhl. Slippery elm	B, c	B, C	–	B, D	A, B, C, D
Urtica procera Muhl. in Willd. Tall nettle	–	C	–	–	–
Verbena hastata L. Blue vervain	–	–	–	D	–
Virburnum prunifolium L. Blackhaw	–	–	–	–	B
Vinca minor L. Common periwinkle	–	–	–	–	D
Viola striata Ait. Cream violet	–	–	–	–	C, D

Letter designations: A = Overstory, spring
B = Understory, spring
b = Understory, fall
C = Ground Cover, spring
c = Ground Cover, fall
D = Observation Only

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Indiana Plant Distribution Records

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Genera are listed in the order of their appearance in Deam's *Flora of Indiana* (1); species within each genus are in alphabetical order, and they are followed by the county in which they were collected. Nomenclature is in accord with that used in Gray's *Manual of Botany*, 8th ed., 1950 (2), unless noted.

Ray Weatherholt collected the majority of specimens from Floyd county, and Richard Maxwell collected the majority from Clark. Specimens were also collected by Sharon Applegate, S. W. Barger, D. Barker, D. Coleman, Cindy Denman, G. Doyle, F. Gohman, Linda Hatfield, Charles Henson, J. Holtman, Frank Howard, A. Johnson, Mike Lankert, Tina Leahy, Dennis Lopp, Richard Lyons, C. Miller, Richard Schoen, Jim Singer, Doug Trusner, and K. Waterman. Voucher specimens for all new records are in the herbarium of Indiana University Bloomington.

Taxonomic Entities

Commelina communis, Clark, Floyd. *Uvularia grandiflora*, Floyd. *Allium vineale*, Floyd. *Lilium michiganense*, Clark, Floyd. *Belamcanda chinensis*. Clark.

Juglans nigra, Clark, Floyd, Harrison. *Laportea canadensis*, Floyd. *Asarum canadense*, Floyd. *Rumex acetosella*, Floyd. *Polygonum scandens*, Floyd. *Amaranthus spinosus*, Floyd, Harrison.

Portulaca oleracea, Harrison. *Agrostemma githago*, Floyd. *Silene stellata*, Floyd. *Dianthus armeria*, Clark. *Hydrastis canadensis*, Floyd. *Hepatica nobilis* Schreb. var. *acuta* (Pursh) Steyermark (*H. acutiloba* in Deam), Floyd.

Podophyllum peltatum, Floyd. *Jeffersonia diphylla*, Floyd. *Menispermum canadense*, Floyd. *Magnolia acuminata*, Jefferson. *Liriodendron tulipifera*, Floyd. *Lindera benzoin*, Clark. *Sanguinaria canadensis*, Floyd. *Dicentra canadensis*, Clark.

Iodanthus pinnatifidus, Floyd. *Cardamine douglassii*, Clark. *Mitella diphylla*, Harrison. *Potentilla recta*, Floyd.

Gymnocladus dioica, Clark. *Medicago lupulina* L. var. *glandulosa* Neilr., Clark. *Amphicarpa bracteata*, Floyd. *Galactia volubilis* var. *mississippiensis*, Clark. *Erodium cicutarium*, Floyd.

Oxalis stricta, Floyd. *Linum sulcatum*, Clark. *Zanthoxylum americanum*, Clark. *Chamaesyce humistrata*, Floyd. *Euphorbia dentata*, Clark.

Rhus typhina, Jefferson. *Euonymus atropurpureus*, Floyd. *Staphylea trifolia*, Floyd. *Aesculus glabra*, Clark.

Abutilon theophrasti, Harrison. *Sida spinosa*, Clark, Harrison. *Passiflora incarnata*, Clark, Floyd. *P. lutea* var. *glabriflora*, Floyd.

Panax quinquefolium, Floyd. *Chaerophyllum tainturieri*, Clark. *Torilis japonicus*, Clark. *Erigenia bulbosa*, Clark. *Lysimachia ciliata*, Clark. *L. nummularia*, Floyd. *Gentiana quinquefolia* var. *occidentalis*, Clark.

Phlox amplifolia, Clark. *P. glaberrima* var. *interior*, Clark. *Polemonium reptans*, Floyd.

Hydrophyllum appendiculatum, Floyd. *Phacelia bipinnatifida*, Floyd. *Hackelia virginiana*, Clark. *Mertensia virginica*, Floyd. *Lithospermum canescens*, Clark. *Echium vulgare*, Clark.

Verbena stricta, Clark. *Agastache nepetoides*, Clark. *Lamium purpureum*, Clark, Floyd. *Lycopus americanus*, Clark. *Perilla frutescens*, Harrison.

Verbascum thapsus, Floyd. *Linaria vulgaris*, Clark. *Campsis radicans*, Clark. *Epifagus virginiana*, Floyd. *Plantago lanceolata*, Floyd.

Valeriana pauciflora, Clark, Floyd. *Campanula americana*, Floyd. *Lobelia puberula*, Floyd. *L. spicata* var. *leptostachys*, Clark.

Aster novae-angliae, Clark, Floyd. *Bidens bipinnata*, Clark. *Helenium flexuosum* Raf. (*H. nudiflorum* in Deam), Clark, Harrison. *Senecio glabellus*, Clark.

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Notes on Biogeography and New Records of Rust Fungi in the Great Lakes Region

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Uredinology (the study of rust fungi) includes research in the morphology, phylogeny, and classification of members of this important group of plant pathogenic fungi. This is not a new study, for the first Indiana rust fungus was collected in 1876 (8). Dr. J. C. Arthur published his first manuscript on rust taxonomy in 1883, so the Arthur Herbarium will soon be 100 years old. Biogeography of rust fungi dates back at least to 1929, with Arthur's textbook, *The Plant Rusts*. Our preliminary studies indicate that the Great Lakes area is a promising region for biogeographic studies of rusts. Many of the examples in this paper will be from Michigan, because the geography of the Great Lakes has had clear effects on plant distributions in that state.

At least three procedural problems must be faced. First, geographic information from specimen labels is frequently useless, because it may be out-of-date. A number of Arthur's specimens are from the "Rust Garden" near West Lafayette, Indiana, a small swamp south of town that was a very fertile collecting spot. This was one of two known North American sites for *Triphragmium ulmariae* (DC.) Link in Willd., the rust of *Filipendula rubra* (Hill) Robins. (Queen-of-the-prairie: Rosaceae) (8), but today we cannot locate that swamp. Other labels may be incomplete. For example, one specimen of *Gymnosporangium corniculans* Kern in Arth. (telia on *Juniperus horizontalis* Moench., prostrate juniper: Cupressaceae, MICHIGAN: Leland, 4 June 1909, *Kern*, PUR 11167, TYPE!) is marked "same place as collected last year". Fortunately, we can deduce from the other specimen (*G. corniculans*, aecia on *Amelanchier erecta* Blanch., shadbush: Rosaceae, 7 Sept 1908, *Arthur & Kern*, PUR 11157) that the location is the north end of Lake Leland in Leelenau County, Michigan. In addition, some of our other Michigan collections are marked as from "Ann Arbor, Battle Creek, etc." The packets contain three or more rusted leaf fragments, each presumably from a different spot. However, none of these examples are in the same league as that by E. L. Greene, the California botanist, who once published a species "from a locality known only to myself" (Peter Raven, welcoming comments at Missouri Botanical Gardens symposium, 17 Oct 1981).

Another problem encountered in distribution studies is shown in Figure 1. From a tally of the rust specimens in the Arthur Herbarium, in the Herbarium of Albion College (ALBC) in Albion, Michigan, and in the literature reports, there appears to be a roughly trimodal distribution of populations of rust fungi in Michigan. A small center occurs on Isle Royale, and larger assemblages are found near the Straits of Mackinac and in the south-central part of the state. Careful study reveals that these centers actually reflect a special collecting expedition to Isle Royale in 1930 (16), Arthur's summer vacations in Leland (1908, 1909, and 1913), and the locations of four institutions where mycologists have worked (Michigan State University, The University of Michigan, The University of Michigan Biological Station at Pellston, and Albion College). The conclusion must be that the recorded distribution of rust fungi is a function of the distribution of collectors of rust fungi. Thus, the mid-portion of Michigan remains largely a uredinological *terra incognita*. A

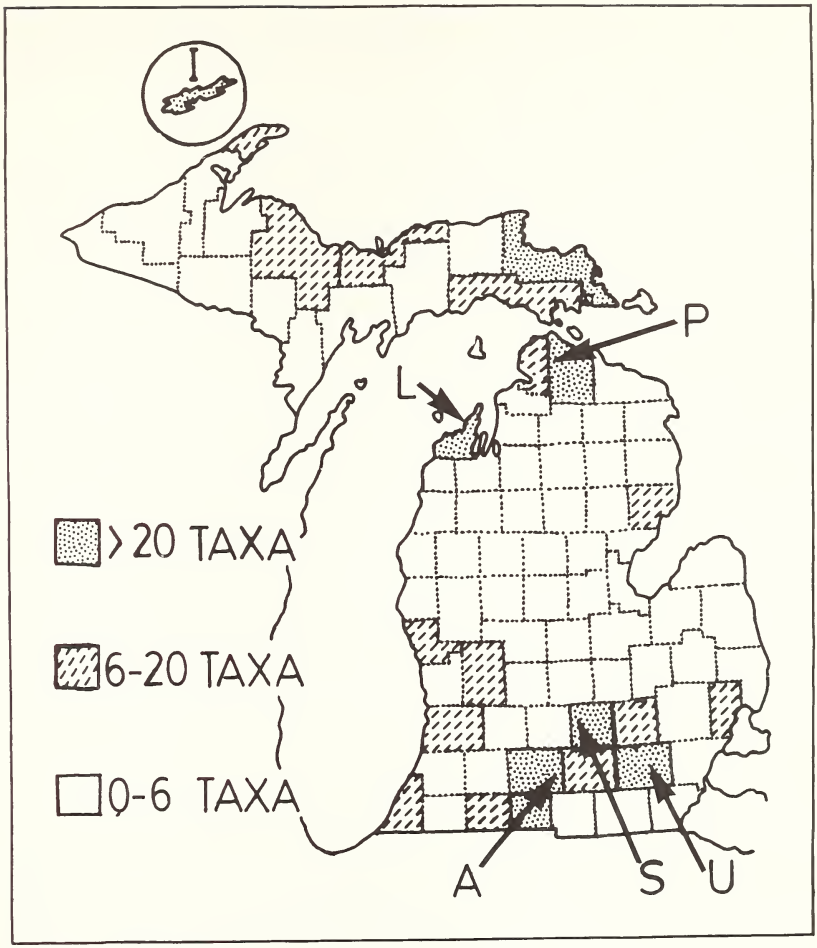

FIGURE 1. Distribution by county of rust species in Michigan, compared with distribution of mycologists. *A-Albion College, I-Isle Royale National Park, L-town of Leland, vacation site of J. C. Arthur, P-The University of Michigan Biological Station at Pellston, S-Michigan State University, U-The University of Michigan.*

similar analysis for Indiana is even more striking: apparently over 70% of Indiana rust fungi occur within easy collecting distance of West Lafayette! Therefore, although North America is botanically well-studied, compared to the tropics, for example, more rust collecting is still needed in the Great Lakes region, especially of rare species. Insufficient data are available because insufficient field work has been done.

Finally, rust fungi may sporulate at times of the year when the host is not flowering or may deter the host from doing so. Some rust collections consist of only the small portion of the host plant that bears the sori, such as a three-inch piece of a grass or sedge leaf blade. Consequently, the identify of the host plant may be difficult to verify.

One factor is on our side, however. Based on Arthur Herbarium records, only about 175 rust taxa are known from Michigan. Tropical workers have to contend with many more rusts. If El Salvador were the size of Michigan, it would have three times as many rust species.

Biogeography of Rust Fungi: Notes on Great Lakes Species

A goal of any taxonomist is to identify the true relationships of the organisms being studied. Rust taxonomy has often been based on a purely morphological basis or on host ranges. Many rusts cannot be identified until the host plant is named. Other characteristics must be evaluated if rust species are to represent true biological species, e.g., the type of life cycle of the rust. Because biogeography has been used with success by taxonomists of higher plants, we decided to test its application to rust taxonomy in the Great Lakes region. Although Arthur (2) wrote that rust biogeography would be difficult until there was agreement on what all the rust species were, it appears now that biogeography will help determine the identity of the species.

Some preliminary patterns of species distributions are evident among the rust fungi of the Great Lakes area. i) Many rusts are widely distributed in North America, whereas ii) some species are endemic to the Great Lakes. iii) Other species reach the extremes of their ranges in this area, especially those with western affinities, such as those infecting prairie plants. iv) At least three patterns of disjunct distributions can be identified involving Great Lakes rusts: (a) some have their main ranges in the Great Plains or the Rocky Mountains, (b) some are centered on the East Coast, and (c) some have disjunctions that are not easily explained. An example of the latter is the *Filipendula* rust mentioned previously, which is known from Europe, Siberia, and Japan, but only from West Lafayette and Dayton, Indiana, in the Western Hemisphere. v.) The final group includes the introduced rust species, which would give spurious results if not recognized as exotics.

Rusts of Wide Distribution

Indigenous species are defined as natives of a given region, but that region is not necessarily a restricted one. Some rusts have native ranges that extend over large portions of North America, including the Great Lakes states. Two examples are *Coleosporium asterum* (Diet.) Syd., with aecia on pine needles (*Pinus*: Pinaceae) and uredinia and telia on asters (*Aster*: Compositae), and *Pileolaria brevipes* Berk. & Rav. on poison ivy (*Toxicodoendron radicans* (L.) Kze.: Ancardiaceae).

Endemic Rust Species

Endemic species are found in restricted areas. Thus, they could be either young species that have not had time to spread widely, or old species that are the remnants of their lineage. Some of the Great Lakes endemic rusts that have been identified so far may be young species because they have morphological characters that are often considered advanced in rust, e.g., wall sculpturing and deciduous pedicels, and may occur on advanced hosts. An example is *Puccinia erigeniae* (Orton) Arth., an autoecious rust of *Erigenia bulbosa* (Michx.) Nutt. (harbinger-of-spring: Umbelliferae). It is known from Ontario, Canada, Ohio, and Michigan (12) (specimen examined: OHIO: Highland Co., Bunker Hill, near Lynchburg, 5 May 1975, *Cooke 49736*, PUR 66172). Another is *Ravenelia opaca* Diet., an endemic rust so restricted in its range that it probably is now extinct. This lost *Ravenelia* species is known only from a single collection on honey locust (*Gleditsia triacanthos* L.: Leguminosae, ILLINOIS: Union Co., Clear Creek, 13 Aug 1890, *Earle*, PUR 6508).

A third example of an endemic rust is *Uromyces halstedii* DeT. Trilliums are aecial hosts of this rust in Illinois, Wisconsin, and Quebec (Arthur Herbarium records) but are best known as hosts in Taughannock Falls St. Park near Ithaca, New York (4). A recent collection on *Trillium grandiflorum* (Michx.) Salisb. (Liliaceae) by William Bridge Cooke from southern Ohio is the first report for that state: Pike Co., Pike Lake St. Park, 11 June 1966, *Cooke 37036* (PUR 66194). The telial hosts of this rust are *Brachyelytrum erectum* (Schreb.) Beauv., *Leersia oryzoides* (L.) Sw. (rice cutgrass), and *L. virginica* Willd. (Gramineae). However, the relationship of *Leersia* to this species should be reviewed because (i) there are slight but consistent differences in the rusts on *Brachyelytrum* and on *Leersia*, (ii) inoculation of cutgrass with aeciospores has not been done, and (iii) these hosts have different ecological preferences and are assigned to different tribes of the grass family.

Puccinia paradoxica Ricker, on *Melica smithii* (Gray) Vasey (Gramineae), is known only from Alger County in Michigan's Upper Peninsula and from one phanaerogamic specimen from Emmet County, Michigan (10 mi S of the Straits of Mackinac, cited in 12). The distribution of the host is Upper Michigan, the Black Hills, and the Pacific Northwest, so the rust is limited to a disjunct population of the host. There is no evidence to determine if this rust diverged from another rust on Tribe Meliceae after *P. paradoxica* was isolated or if the rust has become extinct in the remainder of its old range.

Rust Species at the Extremes of Their Ranges

Species of flowering plants at the limits of their present range comprise 45% of the Indiana flora (15). Range limits also are known for rust fungi in this region. Some species of rusts reach the eastern extremes of their continuous ranges in Michigan's Upper Peninsula or near the southern Great Lakes at the edge of the prairie biome. *Puccinia grindeliae* Peck is a rust of Compositae, tribe Astereae, that is most common in the southern Rockies, but extends into our area to southwestern Wisconsin and to Isle Royale (16). The easternmost collection record for *Uromyces coloradensis* Ell. & Ev., a Great Plains rust species, is from Porter County, Indiana, on *Vicia americana* Muhl. (vetch: Leguminosae, June 1916, *Deam*, PUR 35315). Another Indiana example is *Puccinia vexans* Farl. on *Bouteloua curtipendula* (Michx.) Torr. (side-oats grama grass: Gramineae, Tippecanoe Co.: bluffs above Wea Creek S of State Road 25, near Shadeland, 24 June 1933, *Cummins & Smucker*, PUR 45685).

Rust Species with Discontinuous Distributions

(a) Rust species that have range discontinuities may be detected by careful mapping of collection records. The first task was to identify them; the unfinished job is to explain them. Recently, Marquis and Voss (13) reviewed western U.S. flowering plant species with separate populations in the Great Lakes region, especially near Lake Superior, and the possible explanations for these patterns. Many such answers involve patterns of glaciation to cause the wide range, and then Sears' Xerothermic Period to produce the discontinuities. Rusts with such disjunctions include *Pileolaria patzcuarensis* (Holw.) Arth. on fragrant sumac (*Rhus aromatica* Ait.) and skunkbush (*R. trilobata* Nutt.: Anacardiaceae), which occurs from Mexico to Colorado and on the eastern shore of Lake Ontario. Thus, this rust is not uniformly distributed, although its hosts are.

Other examples include *Phragmidium ivesiae* Syd., a rust of the western U.S. cordillera that first appeared in Ontario about 25 years ago (18). Three new collections are known from Michigan, all on *Potentilla recta* L. (creeping cinquefoil:

Rosaceae): Calhoun Co.: Albion, 1960, *Stowell*, (in ALBC); Leelenau Co.: Lighthouse Point Park, 7 mi N of Northport, 7 Aug 1978, *Ono 78US-405* (PUR 65635); and Montcalm Co.: Flat River St. Game Area, 2 mi N of Belding, 27 July 1980, *McCain 80016 (PUR 66324)*. *Uromyces amoenus* H. & P. Syd. on *Anaphalis margaritacea* (L.) B. & H. (pearly everlasting: Compositae) is known from "Wyoming to northern California and British Columbia" (5, p. 203), except for a collection from Rock Harbor on Isle Royale, Michigan (16). Povah (16) also collected, at the same location,. *Uromyces fragilipes* Tranz. on *Deschampsia* sp. (Gramineae), a rust known previously only from the Pacific Northwest and from the Eastern Hemisphere.

Puccinia sporoboli Arth. var. *robust* Cumm. & Greene occurs on *Calamovilfa longifolia* (Hook) Hack. var. *magna* Scribn. & Merr. (sand-reed grass: Gramineae—specimen examined: MICHIGAN: Mason Co., Manistee National Forest, 22 Aug 1978, *McCain 78154*, PUR 65930). Voss (19, p. 192) indicated that the hosts in the Lake Huron and Lake Michigan area are of this more open-panicled variety, not listed by Cummins and Greene (6). Figure 2 shows the disjunct distribution of this rust: the sand hills and plains of western Nebraska, eastern Colorado and southeastern Wyoming, and over 400 miles to the east, the sand dunes of the Upper Great Lakes. Aecia on *Smilacina stellata* (L.) Desf. (starry Solomon's seal: Liliaceae) or *S. racemosa* (L.) Desf. (false Solomon's-seal) have been shown by association and by inoculation to be part of the life cycle of *P. sporoboli* var. *robusta* in the eastern section of the range. Most of the western telial material alternated with aecia on *Yucca* spp. (Liliaceae) (6). However, one *Smilacina* specimen is known from Denver, Colorado, and Baxter (4) produced aecia on *Yucca* in Wisconsin by inoculation. This tendency for the two geographic rust groups to have different aecial hosts suggests tht the potential for speciation exists, but as yet, no morphological variation can be recognized between the two groups. Note: PUR 49822 is on *Calamovilfa* from Luce Co., Michigan, a county not marked in the distribution map of Voss (19).

(b) A second group of disjunct species in the Indiana vascular plant flora is centered in the Atlantic coastal plain (9). One rust that fits this distribution pattern

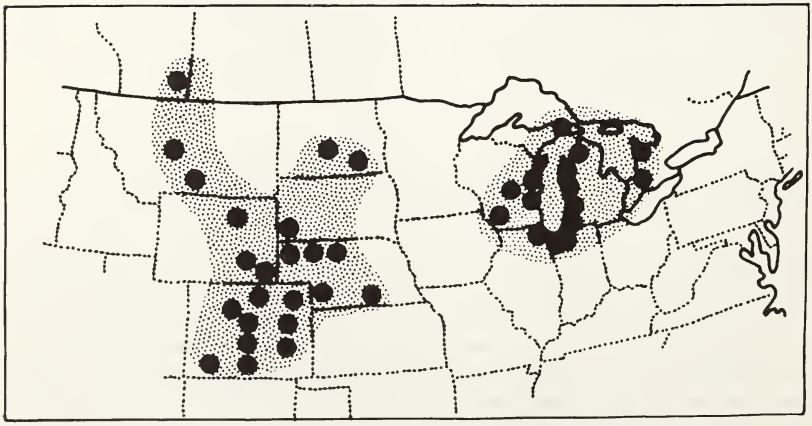

FIGURE 2. Distribution of Puccinia sporoboli Arth. var. robusta Cumm. & H. C. Greene on sand-reed grass. *Information from Arthur Herbarium collection records.*

is *Puccinia sparganioides* Ell. & Barth., with telia on saltmarsh grass along the East Coast (*Spartina alterniflora* Loisel, *S. cynosuroides* (L.) Roth., and *S. patens* (Ait.) Muhl.: Gramineae) and on prairie cordgrass (*S. pectinata* Link) from northwestern Ohio to the Great Plains (Fig. 3). This disjunction may be due to dispersal up the Hudson River corridor. Because these rusts have not yet diverged in morphology, the geographic isolation seems too recent to be due to the uplift of the Appalachian Mountains. Our previous aecial host record for Indiana was pumpkin ash (*Fraxinus profunda* Bush, Oleaceae, Posey County: in swamp 10 mi SW of Mt. Vernon, 15 June 1918, *C.C. Deam*, PUR 22447). Evans-Ruhl *et al.* (7) reported a new record for Indiana on white ash (*Fraxinus americanus* L., Jay Co., Redkey, 9 July 1981, Purdue Plant Disease Diagnostic Clinic specimen, PUR 66307).

(c) Finally, there is one other group of rust species with disjunct populations in the Great Lakes—the ones that do not seem to fit any pattern. They are far easier to identify than to understand. We exclude those obviously brought in on imported plants, e.g., the tropical *Cerotelium fici* (Butl.) Arth. on a fig tree (*Ficus carica* L., Moraceae, MICHIGAN: Ann Arbor, 1917, *Povah*, PUR 5546, presumably a greenhouse plant) and the western rust *Cumminsiella mirabilissima* (Peck) Nannf. on cultivated grape holly (*Mahonia* sp., Berberidaceae) in Michigan (1). Some examples on wild plants include:

1) *Cerotelium tanakae* Ito, on *Amphicarpa* spp. (hog-peanut: Leguminosae), is known, outside of Japan, only from one collection on *A. bracteata* (L.) Fern from Brown County, Indiana (5).

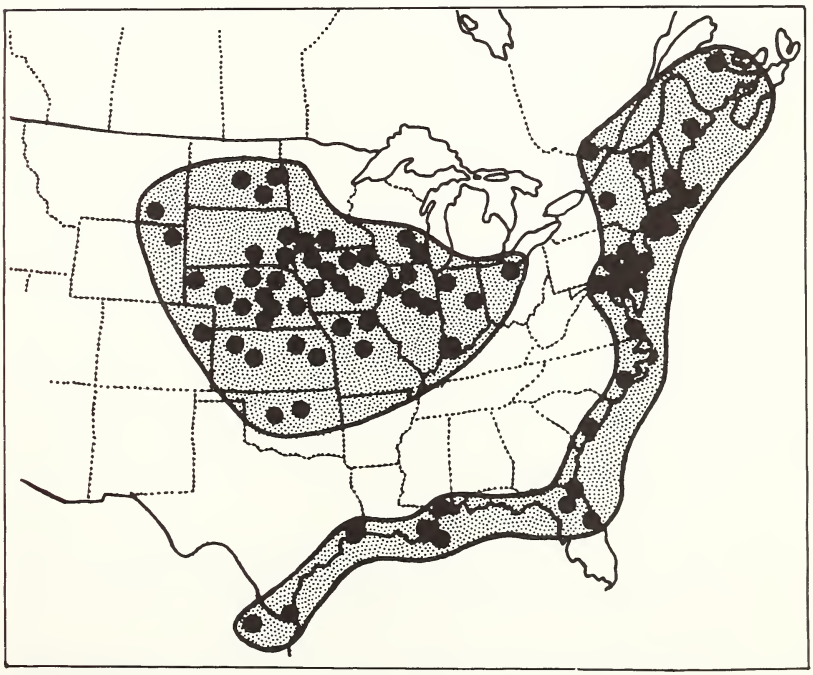

FIGURE 3. Distribution of cord-grass rust, *Puccinia sparganioides* Ell. & Barth. *Information from Arthur Herbarium collection records.*

2) *Puccinia andina* Diet. & Neg. has been found on *Ranunculus* spp. (buttercup: Ranunculaceae) only in Mexiio, Chile, and Argentina, and from Chicago (8).

3) *Puccinia polemonii* Diet. & Holw., on *Polemonium* spp. (Jacob's-Ladder: Polemoniaceae), is known from Scandinavia, Siberia, Alaska, and the Pacific Northwest United States, and on *P. reptans* L. from Half Moon Pond in Posey County, southwestern Indiana. (12).

All three of these rusts were found in our area on native plants. It is unlikely that they were imported, but we cannot explain their distributions. No plate tectonic theory, to date, has suggested a close connection between Japan and central Indiana.

Puccinia andina and *P. polemonii* are known only in the telial state and are presumably microcyclic. One well-accepted route of evolution in rust fungi is life-cycle shortening, with restriction to the aecial host of the former full-cycled species. It would, then, appear reasonably to find widely scattered short-cycle derivatives. This might explain these peculiar disjuncts, except that there are no likely candidates for parental species for the rusts cited here.

Biogeography of Rust Fungi: Summary

Rust biogeography is an attempt to discover relations between rust fungi by study of their historic dispersal trends. Ecological ranges should be studied as well as geographic and host ranges. In addition, because rust fungi are obligate parasites of flowering plants, gymnosperms, ferns, and possibly even mosses, the biogeography of rust fungi is inevitably and intimately correlated with the distribution of their host plants. Rust biogeography is clearly the junior discipline, and few principles are yet available, except in the writings of D. B. O. Savile and E. E. Leppik. A few that may be proposed include:

i) Rust distributions can be a function of their spore dispersal methods. The urediniospores of wheat stem rust (*Puccinia graminis* Pers.) can spread the species, by wind dispersal at high altitudes, more readily and more widely than the teliospores which remain in place on wheat stubble.

ii) Rust fungi cannot be more widespread than their hosts, unless they can adapt to new hosts on which they can spread farther. Host "jumping"has been a major speciation method in rust fungi. Thus, in a given area, if the host does not occur, the rust probably does not, either. However, the converse of this rule does not necessarily follow.

iii) The centers of origin of rust fungi (centers of genetic diversity) are correlated with the centers of their hosts. However, rusts of economic crops, artificially spread with their hosts, will show human influence and not any natural patters of distribution or variation. Common coffee rust (*Hemileia vastatrix* Berk. & Br.) is now known throughout the world wherever coffee is grown, but it probably originated with its host in Ethiopia.

iv) Topography can noticeably affect even those rusts with efficient wind dispersal adaptations. The gray coffee rust (*Hemileia coffeicola* Maubl. & Roger) has been limited in its spread by its preference for the climates of African mountains and its inability to survive in the intervening lowlands.

v) Because of their ability to jump to new hosts, heteroecious long-cycled rusts or rust species groups may be more widely distributed than species groups in which autoecious cycles are the rule (10). However, in very stable climates (e.g., the tropical rain forest, where host alternation may be superfluous) or in very extreme

climates (deserts or the arctic, where host alternation is risky), autoecism or various kinds of shortened life-cycles may be favored.

vi) Some rust fungi have ranges co-extensive with their hosts, e.g., *Cumminsiella mirabilissima*, but others are known from only a limited portion of the range of their host plants.

In summary, the Great Lakes area appears to be a region in which useful rust biogeography studies can be done. A number of new host or distribution records for rust fungi in the Great Lakes region (*sensu lato*) were discovered in this study and are listed in Table 1. Incidental to this work, we also found several new Indiana county records for flowering plants (Table 2).

TABLE 1. *List of new rust or host records*

A. New Host Species Records for Rust Rungi

1. *Frommea obtusa* (Str.) Arth, uredinia on *Potentilla simplex* Michx. (Creeping cinquefoil: Rosaceae), MICHIGAN: Calhoun Co., Whitehouse Nature Center of Albion College, 25 Aug 1978, *McCain 78181* (PUR 65928, ALBC). Some earlier collections may have been on this host, but were combined under *P. canadensis* L.

2. *Puccinia caricina* DC. (*Puccinia pringsheimiana* Kleb. fide Savile, 1973), uredinia on *Carex davisii* Schw. & Torr. (Cyperaceae), INDIANA: Tippecanoe Co., Tippecanoe Battlefield National Historical Monument, 8 June 1978, *McCain 78035* (PUR 66322), in association with spermogonia and aecia on *Ribes cynosbati* L. (Gooseberry: Saxifragaceae), 13 May 1978, *McCain 78017* (PUR 66323). First report of this rust on this host species.

3. *Puccinia caricina* DC., uredinia and telia on *Carex gracilescens* Steudel, INDIANA: Miami Co., 7 ½ mi S of Peru, 9 May 1978, *Clark* (PUR 65622). First report of a rust on this host species. Savile (17), because of the need for careful host-range and biogeographic studies of the rust species complexes on *Carex*, proposed a "moratorium" on collection of them except where an aecial host connection could be demonstrated. This requirement is fulfilled with the *Carex davisii* rust, but the *C. gracilescens* record could not be published under this standard. The proximity of this collection to either *Ribes* or *Urtica* (stinging nettle) is unknown. In either case, *C. gracilescens* would be a new host species, so mention of it seems warranted. Other species in *Carex* sect. *Gracillimae* (e.g., *Carex plantaginea* Lam. and *C. blanda* Dewey) produce aecia on *Ribes* spp. (including *Grossularia*) and not on *Urtica*.

4. *Puccinia dioicae* P. Magn., uredinia and telia on *Carex annectans* (Bickn.) Bickn. (Cyperaceae), INDIANA: Vigo Co., Kieweg Woods, 5 mi SW of Terre Haute, 19 Sept 1980 (6th Annual A. H. Smith Great Lakes Mushroom Foray), *McCain 80032* (PUR 65993). First report of rust on this host species.

B. Records of Rust Range Extensions

1. *Gymnosporangium clavipes* Cke. & Peck, telia on *Juniperus virginiana* L. (Eastern red cedar: Cupressaceae), INDIANA: Tippecanoe Co., bluffs above Wildcat Creek, 2 mi NE of Lafayette, 23 April 1981, *McCain 81001* (PUR 66234). New northwest range extension for this rust on this host. The former western distribution line ran from near Niagara Falls in Ontario, Canada, through Madison, Indiana, to Texas. Although the range of the host extends to mid-Nebraska, and the rust is found west to Mexico and British Columbia, the host west of Ohio and southern Ontario has been *Juniperus communis* L. var. *depressa* Pursh. (14).

2. *Puccinia malvacearum* Bert. & Mont. in Gay, telia on *Althea rosea* (L.) Cav. (hollyhock: Malvaceae), MICHIGAN: Midland Co., Midland, Dow Gardens, 28 July 1980, *McCain 80020-A* (PUR 66329)—ca. 70 mi NE of any specimen recorded in PUR. The host is an introduced ornamental, and the rust is Eurasian in origin.

3. *Puccinia podophylli* Schw., telia on *Podophyllum peltatum* L. (May apple: Berberidaceae), MICHIGAN: Montcalm Co., 1 ½ mi S of Sheridan, 27 July 1980, *McCain 80018* (PUR 66325)—extension of range of rust 50 mi to NW.

C. New Indiana Host Records for Rust Fungi

1. *Coleosporium campanulae* Lev. ex Kickx., uredinia and telia on *Campanula rapunculoides* L. (bell flower: Campanulaceae), Lake Co.: 1 mi S of Cedar Lake, 26 July 1978, *Ono 78-US-337* (PUR 65631).

2. *Puccinia anemones-virginianae* Schw., telia on *Anemone canadenis* L. (thimble-weed: Ranunculaceae), Tippecanoe Co.: wet bluffs above Flint Creek, 3 mi W of West Point, 26 July 1978, *McCain 78094* (PUR 65629).

3. *Puccinia dioicae*, telia on *Carex communis* L. H. Bailey, Martin Co.: 1 mi W of Shoals, 5 May 1940, *Kriebel 8770* (PUR 65623- ex PUL).

TABLE 1.—Continued

4. *P. dioicae*, telia on *Carex rosea* Schk. (in association with aecia on *Solidago* sp., goldenrod: Compositae), Tippecanoe Co., McCormick's Woods Forestry Laboratory of Purdue University, just W of West Lafayette, 27 June 1978, *McCain 78059* (PUR 66326).

5. *P. helianthi* Schw., telia on *Helianthus microcephalus* T. & G. (small wood sunflower: Compositae), Dubois Co.: Jasper, Purdue plant disease clinic specimen *W80288*, ident. 20 Oct 1980 by J. W. McCain (PUR 66053). New Indiana reservoir host for sunflower rust.

6. *P. malvacearum*, telia on *Malva neglecta* Wallr. (mallow: Malvaceae), Steuben Co.: Ashley, in strawberry patch, 30 May 1979, Purdue plant disease clinic specimen *79276* (PUR 65784).

7. *P. sparganioides*, aecia on *Fraxinus americana* (see text).

8. *Puccinia striiformis* Westend. ("stripe rust") on *Triticum aestivum* L. (wheat: Gramineae), Carroll Co., 29 May 1981, *Schall* (PUR 66331).

9. *Uromyces triquetrus* Cke., aecia on *Hypericum kalmianum* L. (St. John's-wort: Hypericaceae), Porter Co.: Indiana Dunes National Lakeshore, West Beach Unit, 29 July 1978, *McCain 78112* (PUR 65630).

D. New Records for Rust Fungi in Other Great Lakes States

1. *Coleosporium campanulae*, uredinia on *Campanula rapunculoides*, MICHIGAN: Leelenau Co., Lighthouse Point, 7 mi N of Northport, 23 Aug 1978, *McCain 78166* (PUR 65928)—new host for Michigan.

2. *P. dioicae*, telia and scant uredinia on *Carex aenea* Fern., MICHIGAN: Keewenaw Co., Porter Island, Isle Royale Nat. Park, 11 Sept 1961, *Shelton 189* (PUR 66330, ex PUL 37002)—new host for Michigan. Previously reported from Minnesota, Wisconsin, and Montana.

3. *P. iridis* (DC). Wallr., uredinia on *Iris tectorum* Maxim. (Iridaceae), OHIO: Hamilton Co., Anderson Twp., 17 Sept 1974, *Cooke 49483* (PUR 66205)—new host for Ohio.

4. *P. malvacearum*, telia on *Malva rotundifolia* L. (cheeses: Malvaceae), OHIO: Clark Co., Springfield, Green Twp., 16 May 1976, *Carter* (PUR 65366)—new host for Ohio.

5. *P. polygoni-amphibii* Pers., aecia on *Gewranium maculatum* L. (wild geranium: Geraniaceae), OHIO: Hocking Co., Old Man's Cave St. Park, 30 May 1964, *Cooke 34622-A* (PUR 66020)—new host for Ohio.

6. *Transzschelia pruni-spinosae* (Pers.) Diet., aecia on *Hepatica acutiloba* DC. (liver leaf: Ranunculaceae), OHIO: Highland Co., Fort Hill St. Memorial, 20 April 1963, *Cooke 33995-B* (PUR 66185)—new host for Ohio. This is an anamorph of the rust of wild black cherry.

7. *Uromyces halstedii*, aecia on *Trillium grandflorum*—see text.

TABLE 2. *List of new Indiana county records for flowering plants*

Some of these reports are based upon specimens received for identification by the Plant Disease and Weed Diagnostic Clinic at Purdue University. Plant specimens received with requests for advice on herbicide control treatments sometimes have represented new state or county records, e.g., *Vulpia myuros*—which is listed only as an example. Such records have been excluded from this report, for the plants presumably are not persisting. The clinic specimens that are listed represent either those which are well established or those which were sent in to the clinic for information only. Nomenclature is according to *Gray's Manual of Botany*, 8th ed. (1950).

1. *Sparganium eurycarpum* Engelm. (giant bur-reed: Sparganiaceae), Tippecanoe Co.: swamp near Battle Ground, 9 June 1939, *Cummins 39-84* (PUL 974).

2. *Vulpia myuros* (L.) K. C. Gmel. (foxtail fescue: Gramineae), Whitley Co.: Columbia City, turf-grass farm (presumably extirpated), 26 June 1980, Purdue plant disease clinic specimen.

3. *Alopecurus aequalis* Sobol. (short-awn foxtail: Gramineae), Whitley Co.: Columbia City, 26 June 1980, Purdue plant disease clinic specimen.

4. *A. carolinianus* Walt. (Carolina false-timothy: Gramineae), Washington Co.: near Campbellsburg, 21 May 1979, Purdue plant disease clinic specimen *W79117*.

5. *Chloris verticillata* Nutt. (windmill grass: Gramineae), Jackson Co.: Seymour, 10 Aug 1981, Purdue plant disease clinic specimen *W81-142*.

TABLE 2.—Continued

6. *Phalaris arundinacea* L. (reed canary grass: Gramineae), Tippecanoe Co.: West Lafayette, S edge of Purdue University campus along abandoned railroad tracks, 12 July 1978, *Hennen*.

7. *Cyperus esculentus* L. (yellow nutsedge: Cyperaceae), Tippecanoe Co.: West Lafayette, Purdue University campus, 18 Sept 1963, *Stryker*.

8. *Cyperus tenuifolius* (Steud.) Dandy (= *Kyllinga pumila* Michx.: Cyperaceae), Vanderburgh Co.: Evansville, 31 Aug 1981, Purdue plant disease clinic specimen.

9. *Scirpus fluviatilis* (Torr.) Gray (River bulrush: Cyperaceae), Tippecanoe Co.: Purdue University wildlife area, 8 mi W of West Lafayette, T.23N, R. 6 W, Sect. 12, 17 July 1980, *McCain 80009*.

10. *Carex tenera* Dew. (slender sedge: Cyperaceae), Carroll Co.: 1 mi S of Delphi, 16 June 1978, *Lembi*.

11. *Juncus torreyi* Coville (rush: Juncaceae), Benton Co.: 1 mi SE of Fowler along US Hwy 52, 19 July 1978, *McCain 78088*.

12. *Luzula echinata* (Small) F. J. Herm. var. *mesochorea* F. J. Herm. (woodrush: Juncaceae), Tippecanoe Co.: 3 mi SE of Green Hill, T. 23 N, R. 6 W, Sect. 34, 13 May 1979, *S. Ulrich*.

13. *Castanea dentata* (Marsh.) Borkh. (American chestnut: Fagaceae), Tippecanoe Co.: West Lafayette, in woods about 200 yards west of Purdue University Horticulture Park, July 1978, *Hennen*.

14. *Sagina decumbens* (Ell.) T. & G. (pearlwort: Caryophyllaceae), Vigo Co.: Terre Haute, weed in yard, 5 May 1979, Purdue plant disease clinic specimen.

15. *Myosuros minimus* L. (mousetail: Ranunculaceae), Greene Co.: Worthington, 7 May 1979, *Weathers*.

16. *Berteroa incana* (L.) D. (hoary alyssum: Cruciferae), Tippecanoe Co.: West Lafayette, 720 Vine St., no date, *Hansen* (PUL 9381).

17. *Croton monanthogynus* Michx. (croton, prairie-tea: Euphorbiaceae), Tippecanoe Co., West Lafayette, gravel pit at S edge of Purdue campus, 8 Oct 1958, *Cummins* (PUL 12245).

18. *Lysimachia nummularia* L. (moneywort: Primulaceae), Washington Co.: Salem, 14 June 1979, *Adams*.

19. *Lamium amplexicaule* L. (henbit: Labiatae), Tippecanoe Co.: West Lafayette, Purdue University Horticulture Park, 1 May 1969,. *Derr*.

20. *Houstonia caerulea* L. (Bluets, Quaker-ladies: Rubiaceae), Tippecanoe Co.: West Lafayette, 15 May 1971, *Hewitt*.

21. *Triosteum angustifolium* L. (yellow-flowered horse-gentian: Caprifoliaceae), Randolph Co.: near Farmland, 01 Oct 1979, Purdue plant disease clinic specimen *79-W197*.

Acknowledgments

Some of the plant specimens cited in this report were made available to us by G. Evans-Ruhl, Director of the Purdue Plant Disease and Weed Diagnostic Clinic, and by Susan Ulrich of Green Hill, Indiana. Voucher specimens of rust fungi have been deposited in the Arthur Herbarium of Purdue University (PUR). Flowering plant voucher specimens are in the Kriebel Herbarium of Purdue University (PUL).

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Verbascum virgatum Stokes: an addition to the flora of Indiana, with comparison to *Verbascum blattaria* L.

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Introduction

Experience in many countries has shown that one can easily find numerous rare plants along railroad tracks. Large unused lots in railyards and adjacent to rail lines are often luxuriously overgrown with vegetation that is quite rich in species (9). One such lot in downtown Terre Haute at the corner of First and Spruce streets is the site of collection of the first specimens of *Verbascum virgatum* Stokes found in Indiana.

Verbascum L. is a European genus, five species of which have become established in the northeast United States and four others of which have been reported (3). The species are biennials, producing a rosette the first year and a tall flowering stem the next (4). *Verbascum virgatum* is distributed along roadsides from Cape Breton to southern Ontario, south to South Carolina, Ohio and Texas and in western states, as an adventive, according to *Gray's Manual of Botany* (2). The Ohio record is a single specimen collected in Franklin County in 1891 (7). It is considered a rare adventive in Illinois, where it was collected in Coles and Pulaski counties (8). These three specimens are housed in the herbarium of the Illinois Natural History Survey (ILLS). It is infrequent in the coastal plain of South Carolina and in Moore and Montgomery counties in North Carolina (11). It is reported as adventive along roadsides in Arizona and Utah (12). Abrams reports it as naturalized in southern California along roadsides (1) and Munz reports it also from Frasier County in northern California (10). Large established populations occur on the campus of Occidental College in Los Angeles (13). *Verbascum virgatum* is not considered established anywhere in the northeast United States (3, 4).

Verbascum virgatum strongly resembles the yellow form of *V. blattaria*, and is so described by most authors of floral references (2, 3, 4, 8, 10, 11). Diagnoses are given by Abrams (1) and by Rydberg (12). *V. virgatum* is biennial, the second year stem 5 to 12 dm. in height, simple or virgately branched, glandular puberulent, green to purplish in color. Basal leaves are oblanceolate to spatulate, 10 to 30 cm. in length, somewhat pubescent or glabrous. Cauline leaves are sessile or clasping, lanceolate, 7 to 15 cm. in length, and, along with the basal leaves, have sinuate-dentate to crenate margins. The inflorescence is an open raceme, pedicels one to four per node, shorter than or equaling the ovate bracts. Calyx lobes are lanceolate, 5 to 6 mm. long. The corolla is yellow, the lobes slightly unequal, 25 mm. wide. Stamens are violet villous, with reniform, medifixed anthers. The capsule is globose, 7 to 8 mm. long (1, 12). The karyotype is $2n = 32$ (10).

Methods and Materials

The original specimen, collected in June, 1980 (TER 3643), was determined using available keys (4) and entered into the herbarium of Indiana State University. The authors returned to the site of collection and took photographs of other *V. virgatum* individuals and individuals of the sympatric *Verbascum blattaria* L., a common, established species (2, 3, 4). Floral material of both species was collected

and stored in buffered glutaraldehyde fixative for subsequent scanning electron microscopy. Letters were sent to all registered and known herbaria and plant collections in Indiana to inquire about previous collections and other specimens housed in the state. The herbaria ILL and ILLS were searched for specimens. Electron micrographs of the abaxial and adaxial corolla surfaces, calyx lobe abaxial surfaces, stamens, and pollen of both species were taken using 10 KV at various magnifications on the Amray 1000A scanning electron microscope at Indiana State University. The materials were simultaneously frozen in liquid nitrogen and lyophilized in a Pearse-Edwards tissue-dryer and sputter-coated with gold-palladium alloy, prior to microscopy.

Results

The responses to our letters and telephone calls revealed that no previous collection of *Verbascum virgatum* was made in Indiana. Two specimens are housed at Indiana institutions, one at the Indiana University Herbarium, the other at the Kriebel Herbarium of Purdue University, both collected in Clarendon County, South Carolina, by Leonard and Radford on June 2, 1968. The herbaria ILL and ILLS have no *V. virgatum* from Indiana. The specimen from Terre Haute is thus a state record, and has been so reported in the state registry.

Verbascum virgatum strongly resembles *V. blattaria* in size, habit, and inflorescence pattern. Key characters for separating the species in the field are the greater pedicel length in *V. blattaria*, exceeding the bract and capsule lengths (Figure 1), compared to *V. virgatum* where the pedicel is shorter than the bract or capsule (Figure 2), and the presence of up to four pedicels at some lower nodes of the inflorescence in *V. virgatum* (Figure 3) which does not occur in *V. blattaria*.

Scanning electron micrographs reveal additional differences. The abaxial corolla surface of *V. virgatum* bears, simple, branched, and glandular trichomes (Figure 4) which are lacking in *V. blattaria* (Figure 5). The adaxial corolla surface in *V. virgatum* is smooth (Figure 6) and much rougher in *V. blattaria* (Figure 7). The calyx lobes of *V. virgatum* are densely covered with glandular trichomes, with glands no more than twice the width of the stalk, and numerous filamentous trichomes (Figure 8) whereas *V. blattaria* calyx lobes bear sparser, glandular trichomes only, these with proportionately larger glands (Figure 9). These correspond exactly with *V. blattaria* leaf trichomes described by Hare (5).

Stamen filament trichomes of both species have clavate tips, which are larger, longer, and of more tapered shape in *V. virgatum* (Figure 10) than in *V. blattaria* (Figure 11). Pollen of *V. virgatum* is smaller and more oblate, with colpae meeting at a more acute angle (Figure 12) than *V. blattaria* pollen which is spherical (Figure 13). The wall surface pattern is a finer mesh in pollen of *V. virgatum* than in pollen of *V. blattaria*.

Discussion

The differences in microscopic characters found cannot be considered artifacts of preparation, since the specimens were collected simultaneously, stored together under identical conditions, and processed together. The characters found were verified by reexamination of herbarium material under the dissecting microscope, where the corolla trichomes are barely seen at maximum magnifications. Despite the large superficial similarity of the two species, there is no doubt regarding identification. Although pollen is usually morphologically similar within a genus, the pollen of *V. blattaria* is easily distinguished from pollen of *V. virgatum* in our samples. The amount of rough coating on the corolla and leaf surface is prob-

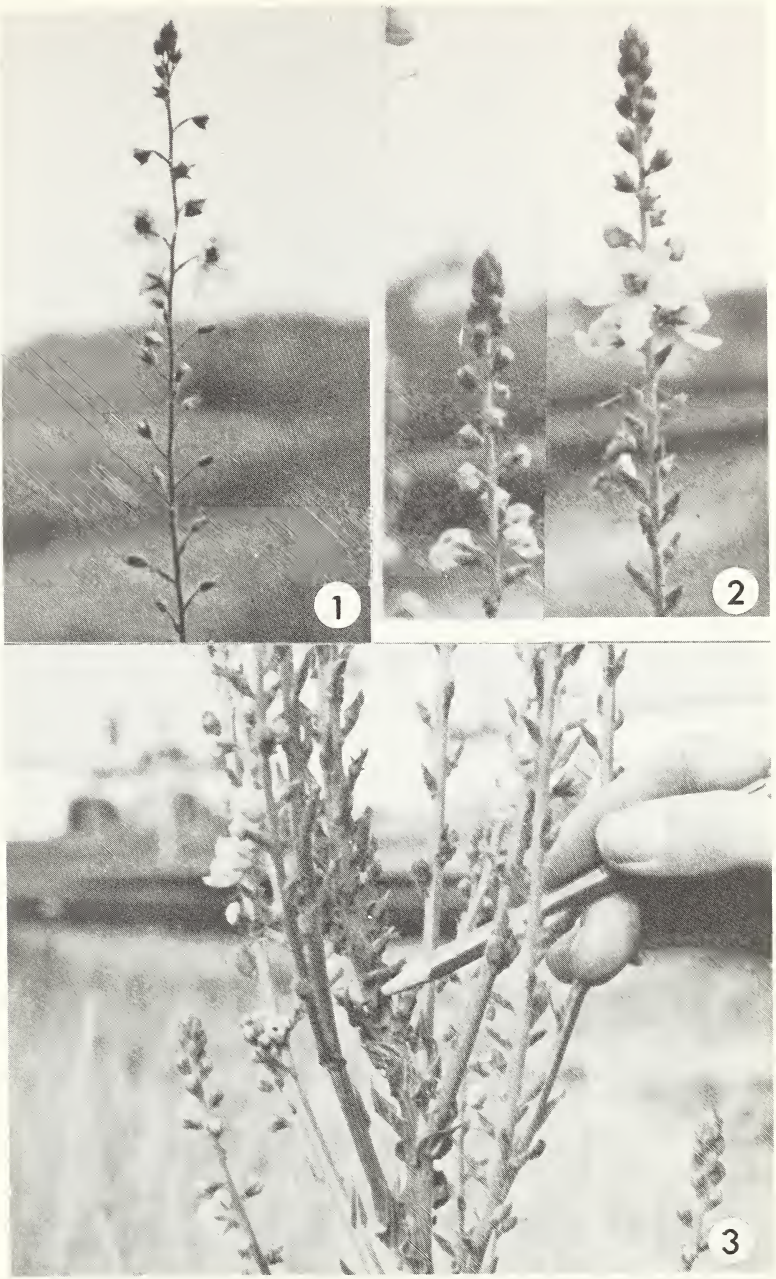

FIGURE 1. Verbascum blattaria *inflorescence*
FIGURE 2. Verbascum virgatum *inflorescence*
FIGURE 3. *Lower node of* V. virgatum *inflorescence with two pedicels*

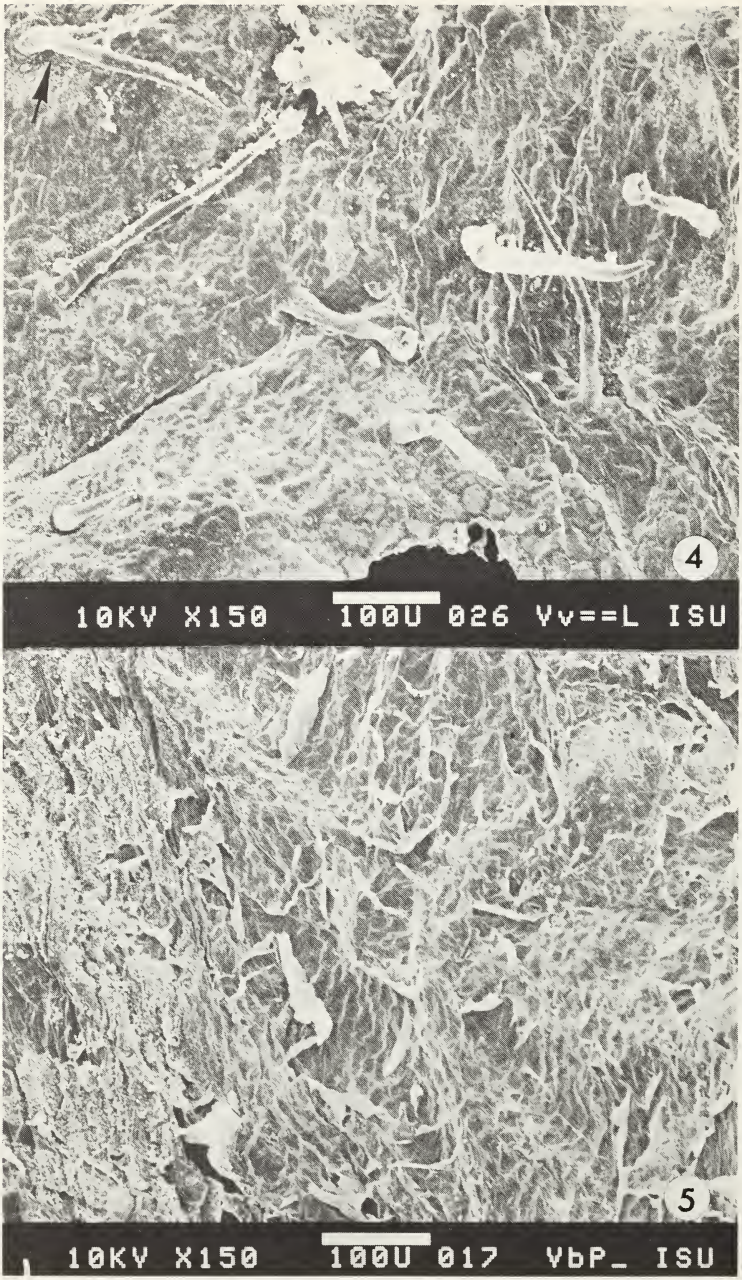

FIGURE 4. V. virgatum *abaxial corolla surface with simple, branched (arrow) and glandular trichomes, X 150*

FIGURE 5. V. blattaria *abaxial corolla surface with blunt-tipped glandular trichomes, X 150*

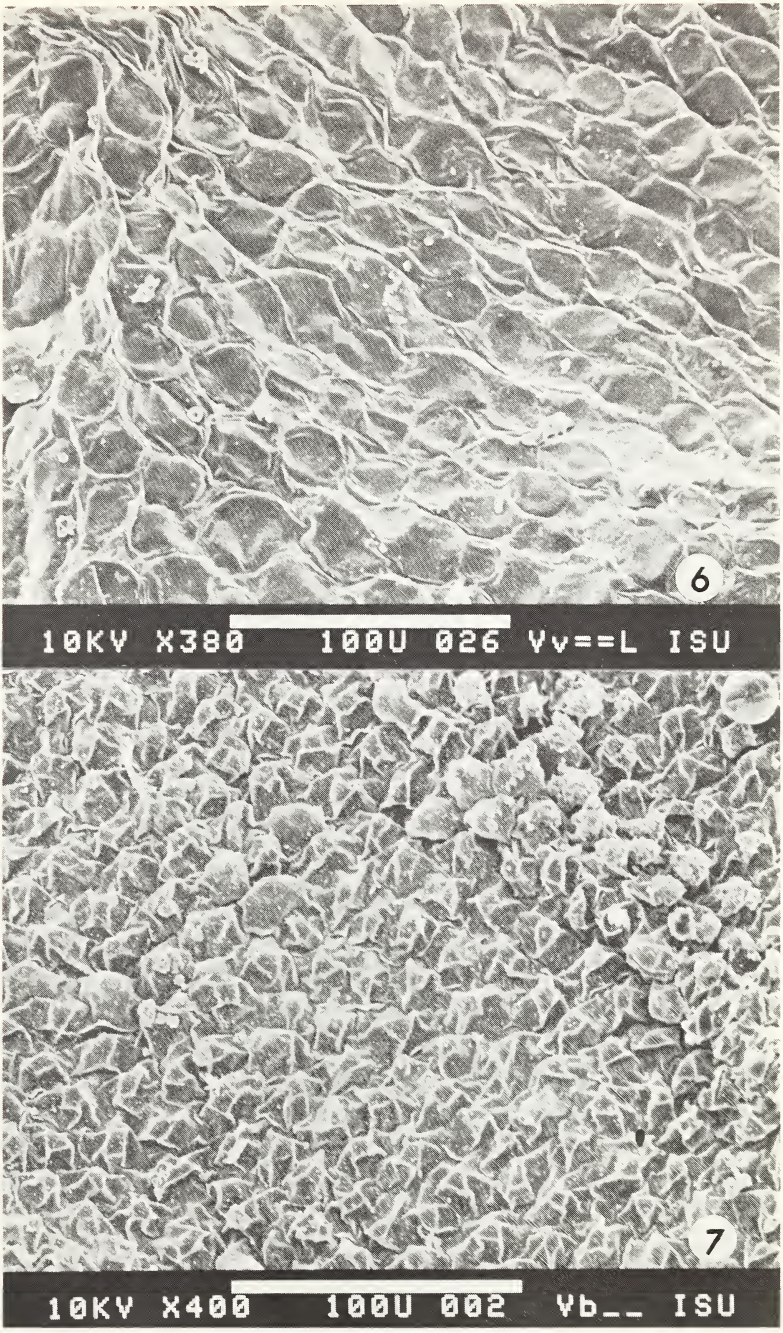

FIGURE 6. V. virgatum *adaxial corolla surface X 380*
FIGURE 7. V. blattaria *adaxial corolla surface X 400*

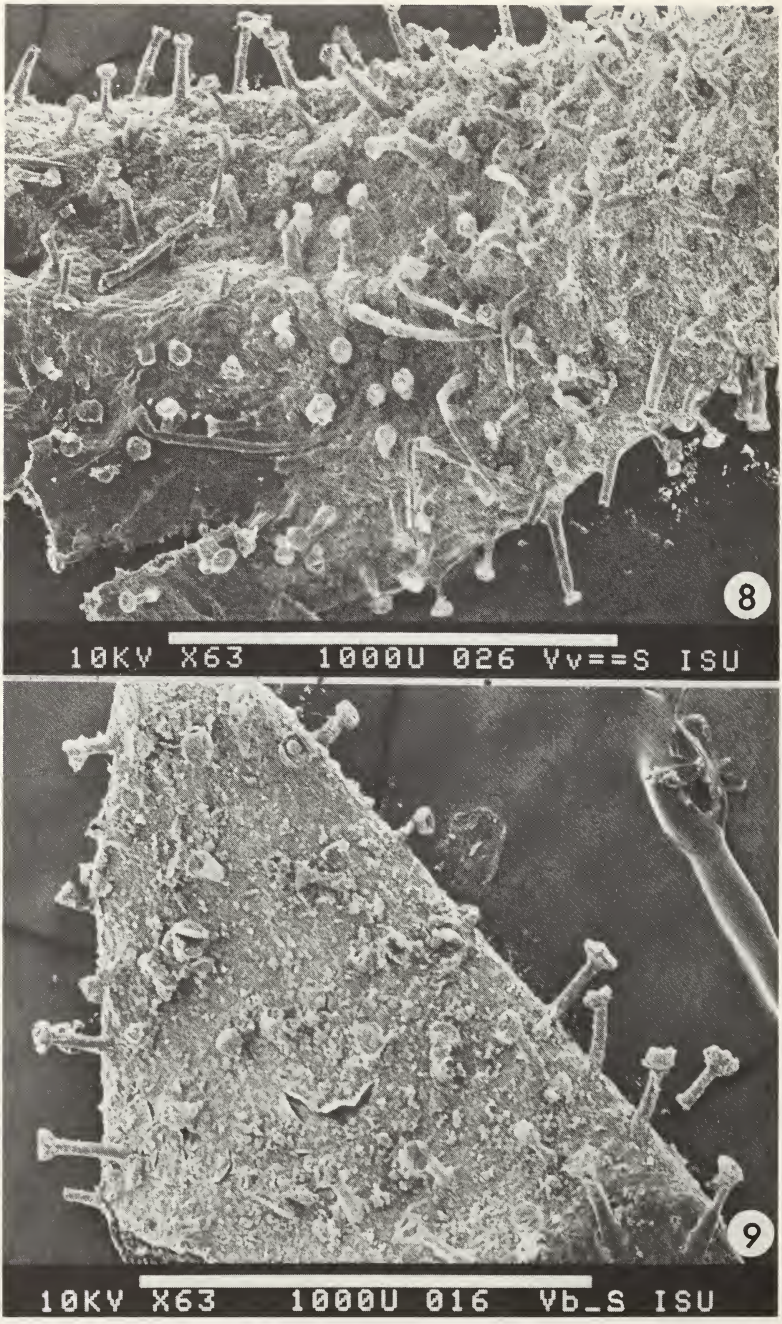

FIGURE 8. V. virgatum *abaxial calyx lobe surface X 63*
FIGURE 9. V. blattaria *abaxial calyx lobe surface X 63*

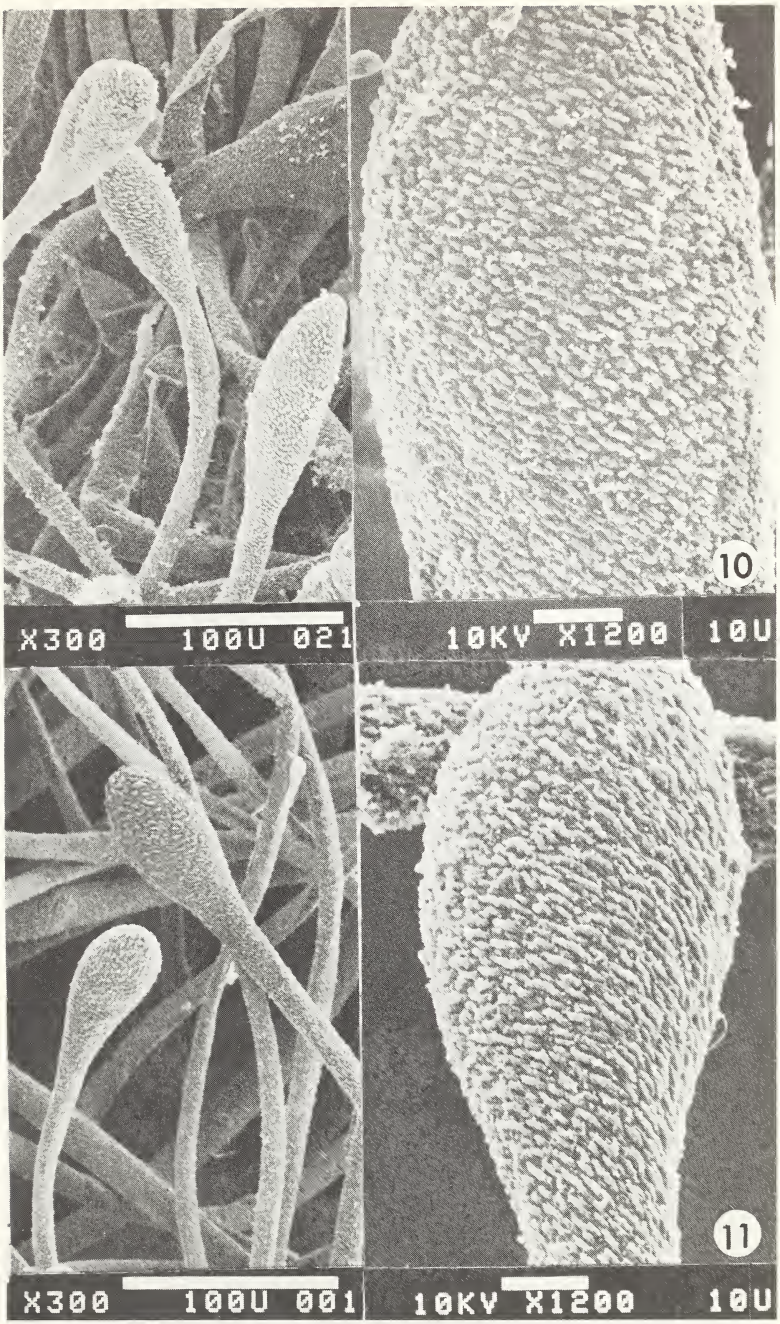

FIGURE 10. V. virgatum *stamen trichomes X 300, tip X 1200*
FIGURE 11. V. blattaria *stamen trichomes X 300, tip X 1200*

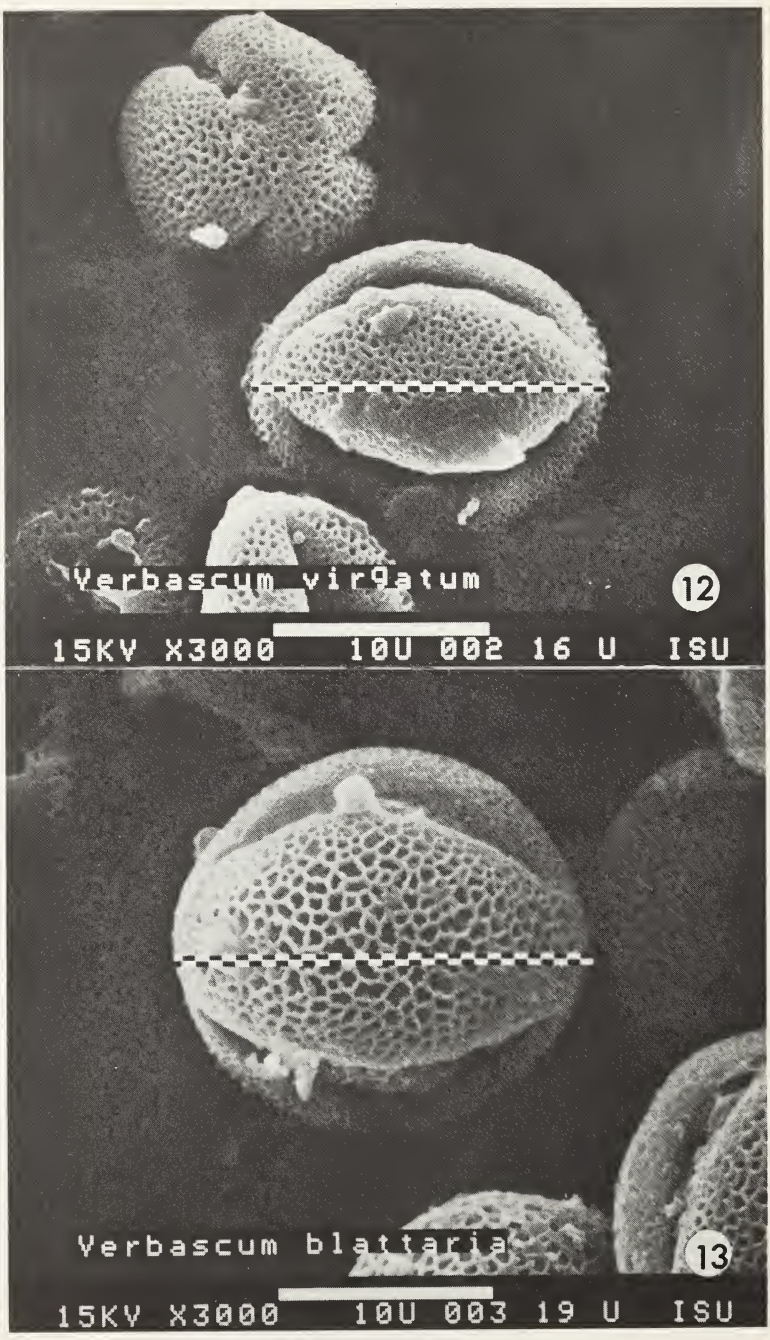

FIGURE 12. V. virgatum *pollen grain X 3000, measurement bar 16 microns*
FIGURE 13. V. blattaria *pollen grain X 3000, measurement bar 19 microns*

ably related to age or weathering of the sample rather than a true species character as it is shown in the micrographs (Figures 8 & 9) to be in patches. The wrinkling of the corolla surface (Figures 6 & 7) may represent either a true species character or differences in maturity or weathering.

A second specimen of *Verbascum virgatum* was collected at the same site in August 1981, and is also housed at Indiana State (TER 3991). Since the species is biennial, we provisionally consider the species established at the Terre Haute site, since it must have been present in rosette form in 1979. If the species flowers again next year at the site we can accept the fact of establishment with reasonable certainty.

Comparison of the seeds of the two species was not possible since the first specimen was collected before capsule maturity and the second was collected late, and the only apparently mature capsules remaining contained no seeds, only weevils and fungi. Poor seed production may be a factor in the failure of *V. virgatum* to become established widely. The seed production of *Verbascum blattaria*, in contrast, is copious, and hundreds of seeds were found by opening a half dozen capsules, and most capsules appear to mature properly on most plants. *V. blattaria* also retains seed viability for very long time, being the only species still germinating in the ninety-year trial in Dr. Beal's seed viability experiment in Michigan (6). These two facts together, fecundity and longevity, explain the success with which *V. blattaria* has become naturalized, in contrast to *V. virgatum*.

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SCIENCE EDUCATION

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ABSTRACTS

An Experiment for Nonscience Majors: The Buffer Capacity of Humus Soil. MARSHALL P. CADY, JR., Department of Natural Sciences, Indiana University Southeast, New Albany, Indiana 47150.——Laboratory experiments for nonscience majors must meet a wide range of objectives. They must introduce students to new concepts, everyday applications of these concepts, and laboratory techniques which quantify the concepts. In this paper the general desirability of these goals is discussee in context of a specific experiment dealing with the buffer capacity of humus soil. The experiment has been performed by approximately 150 students with positive response.

Biology for the Citizen. CHARLES L. GEHRING, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.——The consensus (non unanimous) was that there should be a *single* course for majors and nonmajors, not separate courses (CUEBS News, Vol. IV, No. 3, Feb. 1968). When an introductory course is listed as a prerequisite to other departmental courses does it make sense to have general education/liberal arts students in that course? I think not. There are two distinct groups of students: (1) Those with career objectives that require mastery of biological concepts, processes and principles, and (2) those needing "people" biology. Obviously, there is subject matter to be considered; but more importantly there is a need to whet the student's appetite for additional information on biological topics, and they become scientifically literate.

How does one organize a meaningful course for nonmajors? What topics are included or excluded? It is a fact that 25% of the freshmen entering public colleges/universities drop out during or after the first year, and 65% will never complete a degree program. An introductory biology course is, in fact, a terminal biology course. Therefore, *general* topics are more appropriate than are the details of biochemical pathways, etc., such as are required in courses for majors. I use questionnaires, course/instruction evaluations, and discussion to determine what to offer in the nonmajors course. For example, the data from the Sex Knowledge questionnaire reveal a significant lack of formal sex education or parental discussion of contraceptives, VD, etc. My students do not read American Journal of Botany or Plant Physiology; however, I do encourage them to read Newsweek, Time, Playboy, Cosmopolitan, etc., and I assign readings in such publications.

Most often a course is what the instructor *wants* in terms of content/topics. Perhaps the priority should be determined by student *needs*. We must continuously ask ourselves, *why are we all here*? The answer always must be *to help students learn* (S.N. Postlethwait, JCST Vol. XI, #1, Sept. 1981).

In Quest of the Quark: Teaching an Introduction to Elementary Particle Physics. LINDA HAMRICK, The Canterbury School, Fort Wayne, Indiana.——Introductory

Elementary Particle Physics serves as an initiation to the emerging theoretical framework for matter/energy at the sub-subatomic level. It is not intended as, nor is there any pretense of its being, more than an introduction to basic terminology and principles of a field which can only grow in importance as the years progress. To arm students with enough background so that they may listen to and assess new discoveries as they occur is more than responsible, it is mandated in this rapidly developing field.

The course begins with a brief review of Newtonian Physics and then subdivides topically into eight main areas: 1) Classic subatomic particles; 2) Boson/Fermion distinction (analogous to Energy/Matter components) based on the Pauli Exclusion Principle; 3) Fermion subdivision into Leptons (pointal and conform to the Pauli Exclusion Principle) and Hadrons (can be further subdivided and do not conform to the Pauli Exclusion Principle due to the Strong Force); 4) Lepton types: electrons, muons, tau particles, their respective neutrinos and the antiparticles of each; 5) Hadron types: Baryons composed of three quarks (a proton belongs to this group as does the neutron) and mesons composed of two quarks; 6) Boson classifications as the units of Force (one example is the photon as the boson of the Electromagnetic Force); 7) The Four Forces: The Strong Force, The Electromagnetic Force, The Weak Force, and the The Gravitational Force; 8) Symmetry breaking at the beginning of the Universe, and the unification of forces and particles, historical as well as theoretical.

This course has been offered at various times over the past two years at both Indiana University's Special Abilities Program at Fort Wayne, as well as at The Canterbury School for youngsters ranging from grades seven to twelve. Even in age-mixed classes, with the leveling effect of a good basal review of Newtonian Physics plus a firm introduction to atomic theory and subatomic particle terminology, the student success level has been very high, averaging 95% on post-testing which includes objective, essay and problem solving questions. Interest levels have exceedingly high as well, in fact student interest in the subject from brief mentions of terminology like "quarks" in various printed and electronic media, was that which initiated the course originally.

The historical aspect of this area serves well for students in another manner, for it provides an example of the integrative nature of many scientific breakthroughs, and delves the past in terms of Galileo's work on Terrestial Gravity unifying with Kepler's work on Celestial Gravity, through Newton's insight in *Principia* (1687). The search is yet current, as we watch scientific history take shape in Heisenberg's Quantum Mechanics (1932), Anderson's discovery of the Positron (1936), Gell-Mann/Zweig's prediction of the quark (1963), and the Glahow/Salam/Weinberg work in Weak Interactions (1979).

The effort by Physicists to develop new terminology and theory in the evolving picture of matter/energy is not an attempt to make matter more and more complex, although the confrontation with new terminology sometimes leaves this impression. The effort is, of course, just the oposite. When all units of both matter and energy are contained (albeit theoretically) under the umbrella of a few quarks, leptons, and a handful of force-units called bosons, the entire structure of our universe assumes a marvelous integrity if not simplicity. This structure of Elementary Particle Physics can be utilized to complement Physics as the traditional behavioral underpinnings on which the various scientific disciplines are based.

Be Thankful for Your Science Teaching Problems. STANLEY S. SHIMER, Science Teaching Center, Indiana State University, Terre Haute, Indiana 47809.——At

the end of your teaching day, do you feel like a slick-sleeve Private, or a five-star General? This article may show how you can be a five-star General.

A General controls problems—ordering them around and making them obey him. A teacher deals with the problems of controling children, arranging materials, and providing a good learning environment. Solving these problems is half of the teacher's job; teaching is the other half. If it were not for things that go wrong, your principal could get someone to handle your job for half the price. Excellent teaching is hard work, but it is very satisfying to be able to go to bed each night as a five-star General.

A Report of the Indiana Energy Education Curriculum Project for Elementary, Middle and Senior High School (1979 to 1981). JOE E. WRIGHT, Energy Education Consultant, Division of Curriculum, Indiana Department of Public Instruction, Indianapolis, Indiana 46204.——Phase I (1979) involved developing three units for elementary educators, grades K-6. Energy activities were developed in four areas: Awareness, Understanding, Inquiry Skills and Participation. Evaluation of the materials in Indiana classrooms showed knowledge gains and positive attitudinal changes.

Phase II (1980) involved developing materials for middle/junior high school educators. Two units and a comic, Quantum Conserves, were designed, printed and disseminated. Evaluations by classroom teachers revealed administrative support, major usage in science, community support and potential for future use in 1982.

Phase III (1981) involves developing nine units and a teaching guide for sixteen subject areas for senior high teachers. Materials will be disseminated through ten regional workshops, Energy Education CADRE and local education agency coordinators.

Phase IV (1982) will involve developing and implementing State Plan. The major components of the Plan will include an Energy Education CADRE (Thirty classroom teachers), Community Networking Program, Home Conservation Program, Youth Conservation Program, School Conservation Program and Project NEED (National Energy Education Day).

A Study of the Ages of Indiana Science Teachers and Their Increased Ages over an Eight Year Period (1972-73 to 1980-81)

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Rationale and Source of Data for the Study

The birthdates of all teachers in Indiana public schools are collected annually by the Division of Educational Information and Research, Indiana Department of Public Instruction, in its Report of Certified Personnel (EIR Form 2). These are regularly translated into teacher ages and are available through computer printouts of teachers teaching various grades and subjects. Other than calculating the mean age for all teachers, all male teachers and all female teachers in each teaching assignment category, these data are usually processed no further.

During the spring of 1981, several inquiries were received concerning the projected future supply of various categories of science teachers. It was realized that for answers to these questions to have any validity, some knowledge of potential retirement curves, or age curves, of active teachers would be useful. The most recent comprehensive data relating to these curves was from the 1973 Project FUTEPS study (1). Since the teacher supply/demand picture had changed considerably in the intervening eight years, the need for updated information was readily apparent. Therefore, the Division of Educational Information and Research was requested to further process the age data in its computer file on 1980-81 teachers and provide age tabulations of teachers with various science teaching assignments. Similar tabulations were requested for all secondary (7-12) science teachers, all elementary teachers and all secondary teachers to serve as references in analyzing the status of the various science teacher population.

The Division of Educational Information and Research programmed the State computer to convert the birthdates of Indiana's public school instructional personnel into their chronological ages as of December 31, 1980 and then tabulated these ages for each requested teaching category using the Statistical Package for the Social Sciences. Initial review of these tabulations indicated that the shift in the ages of Indiana high school science teachers over the eight year period (1972-73 to 1980-81) was greater than was generally realized; therefore, a more in-depth comparison of the two sets of data was undertaken.

Since the Project FUTEPS (1972-73) teacher age data was coded into seven 5-year age brackets with open-ended brackets at either end of the age scale before being entered into the computer, the 1980-81 data was retabulated, by hand, into these same age brackets before comparisons of the two sets of age distribution curves were undertaken.

Also, in order to compare the actual number of persons with given teaching assignments in the two sets of data, one additional treatment was performed on the Project FUTEPS data. Those data had been collected by questionnaires completed by science teachers in February, March and April, 1973. Although the questionnaire was distributed to all teachers reported on the 1972-73 EIR Form 2 as having science teaching assignments, only 72% of these teachers returned questionnaires. Since no attempt was made to determine the return rate for teachers of the various science disciplines, it was assumed that the overall return rate applied to each

teacher category (e.i., Biology, Chemistry, etc.) examined. Thus, the number reporting each assignment was multiplied by a factor of 100/72 to approximate the total number of 1972-73 teachers with each teaching assignment. No attempt was made to retrieve the exact teacher assignment data from the 1972-73 EIR Form 2 reports since exact numbers were not as important as downward, or upward, trends in the number of science teachers in Indiana's public schools.

Findings

Science teachers in the 1980-81 study were older than the rest of the secondary teachers who, in turn, were generally older than elementary teachers. The central tendencies of teachers' ages are given in Table 1 and their age distributions in Table 2.

Senior high school (grades 9-12) science teachers were older than their middle/junior high school (grades 7 & 8) counterparts. The mean ages of these two groups differed by 1.4 years, 39.5 and 38.1 respectfully (Table 1). However, the entire middle half of the high school teachers appear to be 2 years older than the center 50% of the 7 & 8 grade teachers since the first quartile ages were 32 and 30 respectively, the median ages were 38 and 36 and the third quartile ages were 48 and 46. Only 4.7% of the high school teachers were 25 or younger while 6.6% of the 7 & 8 grade science teachers were in this age bracket (Table 2).

Among the high school science teachers, earth/space science teachers were the youngest with a mean age of 37.6 and a median age of 36 (Table 1). Physics and chemistry teachers were the oldest with mean ages of 40.9 and 40.7 respectfully; the median age of both groups was 40. Although the measures of central tendencies indicated that the ages of biology teachers were distributed similar to the ages of all high school science teachers, an analysis of the age distributions (Table 2) indicated that the biology teachers may have been slightly older than the high school science teachers generally.

Tables 3 and 4 compare the 1980-81 teacher age data presented in Tables 1 and 2 with the most comparable data available from the 1972-73 Project FUTEPS study. Although the total number of science teachers increased from 1972-73 to 1980-81, the number teaching each specific discipline decreased. Only the number teaching general science increased.

Since the Project FUTEPS teacher age data were coded into open-ended age brackets at both ends of the age scale before being comuter processed, mean ages of the 1972-73 teachers could not be accurately calculated, but median and various percentile ages could be interpolated with considerable confidence. Although teachers were younger in 1972-73 than in 1980-81, the relationships between ages of teachers of the various science disciplines had not changed. In 1972-73, middle/junior high and earth/space science teachers were the youngest science teachers, physics and chemistry teachers were the oldest and biology teacher ages were generally reflective of the ages of all high school science teachers (Table 3).

The age shift that occured over the eight year period was greater than expected. In nearly all high school science teacher categories, the first quartile, median and third quartile ages had moved upward 5 or more years in the eight year period. The median age of physics and chemistry teachers had advanced 7 years.

The nature of these age shifts are apparent when the age distribution curves (Table 4) for the similar teacher populations during the two years are examined. In 1972-73, the modal age bracket for all populations of science teachers was the 26-30 age bracket, but by 1980-81 the mode was the 30-35 bracket for all populations ex-

TABLE 1. *Comparison of Central Tendencies of 1980-81 Science Teacher Ages with Teachers Generally*

Teaching Category	Number	Range	Mean	Standard Deviation	First Quartile	Median	Third Quartile
Elementary	28,694	21-76	38.8	10.9	30	36	47
All Sec.	28,620	22-72	38.7	10.5	30	36	46
Sec. Sci.	4,263	23-71	39.2	10.1	31	38	45
7-8 Science	1,744	23-68	38.1	10.2	30	36	44
9-12 Science	3,141	23-71	39.5	10.0	32	38	46
Biology	1,073	23-67	39.5	9.6	32	38	46
Chemistry	436	23-71	40.7	10.6	32	40	47
Earth/Space	172	23-68	37.6	9.0	31	36	43
Gen. Sci.	739	23-67	38.3	9.9	31	37	44
Phys. Sci.	186	23-68	39.9	10.3	32	39	46
Physics	338	23-70	40.9	10.1	34	40	48

TABLE 2. *Age of Science Teachers 1980-81*

Teacher Category	Grades		Nt	25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	60
General Science	9-12	N	739	45	139	156	135	96	63	48	41	16
		%		6.1	18.8	21.1	18.3	13.0	8.5	6.5	5.5	2.2
Biology	9-12	N	1073	35	167	224	197	176	109	83	52	26
		%		3.6	15.6	20.9	18.3	16.4	10.2	7.7	3.9	2.4
Chemistry	9-12	N	436	22	63	68	84	80	33	23	46	17
		%		5.0	14.5	15.6	19.3	18.3	7.6	5.3	10.5	2.9

TABLE 2.—Continued

Earth/Space Science	9-12	N	172	9	29	45	37	24	9	10	5	4
		%		5.3	16.9	26.2	21.5	13.9	5.3	5.8	2.9	2.3
Physical Science	9-12	N	186	10	27	36	33	29	17	16	11	7
		%		5.4	15.5	19.3	17.8	15.6	9.1	8.6	5.9	3.8
Physics	9-12	N	338	15	39	60	66	56	35	29	29	12
		%		4.4	11.6	17.7	19.6	16.5	10.4	8.6	7.6	3.6
All Science	9-12	N	3141	148	487	625	596	488	289	224	194	90
		%		4.7	15.5	19.9	19.0	15.5	9.2	7.2	6.1	2.9
General Science	7&8	N	1399	86	285	294	255	153	108	92	87	39
		%		6.1	20.4	21.0	18.3	10.9	7.7	6.6	6.2	2.8
Life Science	7&8	N	126	6	28	29	23	13	8	11	8	0
		%		4.8	22.2	23.0	18.0	10.3	6.3	8.8	6.3	0.0
Earth/Space Science	7&8	N	43	4	10	14	6	2	22	2	1	
		%		9.3	23.3	32.5	14.0	4.6	4.7	4.6	4.7	2.3
Physical Science	7&8	N	124	14	24	25	20	17	5	6	9	5
		%		11.3	19.3	20.2	16.1	13.7	4.1	4.8	7.3	3.2
All Science	7&8	N	1744	115	358	370	319	190	125	115	107	45
		%		6.6	20.5	21.2	18.3	10.9	7.2	6.6	6.1	2.6
All Science	7-12	N	4263	222	703	865	803	608	377	294	265	126
		%		5.2	16.2	20.3	18.8	14.3	8.8	6.9	6.2	3.0
All Secondary	7-12	%	28620	6.5	18.6	22.0	16.2	11.5	8.4	7.3	6.2	3.3
All Elementary	1-6	%	28694	6.5	20.3	21.2	14.1	10.9	9.0	8.0	5.6	4.4

TABLE 3 *Comparison of Median, Quartile, and 90th and 95th Percentile Ages of Science Teachers in 1980-81 with those in 1972-73*

Teaching Category	Grade	Year	Number	First Quartile	Median	Third Quartile	90th Percentile	95th Percentile
Secondary Science		1980-81	4,263	31	38	45	55	59
		1972-73**	3,236*	27	32	42	52	57
Middle School Science	7&8	1980-81	1,744	30	36	44	55	58
		1972-73**	1,567*	25	30	40	52	56
High School Science	9-12	1980-81	3,141	32	38	46	55	58
		1972-73**	1,975*	27	33	42	53	57
Biology & Life Science	7&8	1980-81	126	30	35	42	53	57
	9-12	1980-81	1,073	32	38	46	54	58
		1972-73	1,250	27	33	41	52	57
Chemistry		1980-81	436	32	40	47	57	60
		1972-73	599*	28	33	45	52	58
Earth/Space Science	7&8	1980-81	43	29	33	38	52	57
	9-12	1980-81	172	31	36	43	51	56
		1972-73	344*	26	30	38	51	57
General Science	7&8	1980-81	1,399	30	36	45	55	58
	9-12	1980-81	739	31	37	44	54	58
		1972-73	1,226*	25	29	38	51	56
Physical Science	7&8	1980-81	124	30	35	45	57	59
	9-12	1980-81	186	32	39	46	55	59
		1972-73	633*	26	31	43	53	58
Physics		1980-81	338	34	40	48	56	60
		1972-73	456*	28	33	43	53	61

*Number of 1972-73 teachers in each category are calculated numbers on the basis of a 72% overall response and an even distribution of responses among all categories.

**The Project FUTEPS population was divided by the teachers reporting their teaching assignments in middle/junior high school or senior high school; thus, middle school data may include 6th grade teachers and the high school data may not include all 9th grade teachers.

TABLE 4. *Comparison of Science Teachers' Ages in 1980-81 and 1972-73 by Percent in 5 Year Age Groupings*

Teaching Category	Year*	25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	60	Mode
Secondary Science	1980	5.2	16.2	20.3	18.8	14.3	8.8	6.9	6.2	3.0	31-35
	1973	19.4	26.2	16.6	10.1	7.7	7.4	6.0	3.6	2.6	26-30
Middle School Science	1980	6.6	20.5	21.2	18.3	10.9	7.2	6.6	6.1	2.6	31-35
	1973	25.1	27.7	13.2	9.5	6.0	7.0	5.8	3.0	2.7	26-30
High School Science	1980	4.7	15.5	19.9	19.0	15.5	9.2	7.2	6.1	2.9	31-35
	1973	19.4	26.2	16.6	10.1	7.7	7.4	6.0	3.6	2.6	26-30
Biology/Life Science	1980	3.4	15.4	21.1	18.3	15.7	9.8	7.8	5.0	2.2	31-35
	1973	15.8	26.0	18.6	12.9	8.5	6.6	5.2	3.5	2.9	26-30
Chemistry	1980	5.0	14.5	15.6	19.3	18.3	7.6	5.3	10.5	2.9	36-40
	1973	15.8	24.1	18.1	7.9	9.3	10.0	7.6	3.7	3.5	26-30
Earth/Space Science	1980	6.0	18.1	27.4	19.1	12.1	5.1	5.6	3.3	2.3	31-35
	1973	23.0	30.6	15.8	8.0	5.7	6.4	4.9	1.9	3.7	26-30
General Science	1980	6.1	19.8	21.0	18.2	11.6	8.0	6.5	6.0	2.6	31-35
	1973	26.4	28.3	13.5	9.1	5.5	6.7	5.5	3.3	1.8	26-30
Physical Science	1980	7.7	16.8	19.7	17.1	14.8	7.1	7.1	6.5	3.5	31-35
	1973	20.8	26.6	16.4	7.4	8.0	7.9	5.7	3.7	3.5	26-30
Physics	1980	4.4	11.6	17.7	19.6	16.5	10.4	8.6	7.6	3.6	36-40
	1973	13.4	22.6	20.2	11.8	9.7	9.6	5.3	2.8	5.5	26-30

*Ages of teachers for the 1980-81 school year were computer calculated as of December 31, 1980 from reported birthdates on EIR forms while 1972-73 ages were teacher reported ages on the Project FUTEPS survey forms in February, March and April, 1973.

cept chemistry and physics teachers, where the mode had advanced to the 36-40 age bracket. In 1972-73, the under 25 year old bracket, which essentially includes only ages 23 through 25, was the second most populated age group for most science teacher categories. In all cases, at least 15% of the teachers were in this group. In 1980-81, the 36-40 age bracket was usually the second most populated. In no case were more than 8% of the teachers of age 25 and under; less than 5% of the biology, chemistry and physics teachers were in this age bracket. In 1972-73, the percent of science teachers who were 30 or younger ranged from a low of 36% for physics teachers to nearly 55% for general science teachers. In 1980-81, the range for this age group was from 16% for physics teachers to only 27% for middle/junior high school science teachers.

Special attention needs to be given to the chemistry teacher age distribution curves. There was an apparent anomaly in the 1972-73 ages of these teachers. While all other science teacher age curves appeared to peak with the 25-30 age bracket and then fairly closely follow a normal decay curve until retirement age was reached, the chemistry teacher curve dropped more rapidly at first and then rose to a secondary peak at the 46-50 age bracket. Since the 1980-81 data was inclusive of all public school teachers, it was clear that the anomaly was real and not attributable to any sampling error in the Project FUTEPS study as there was a definite secondary mode for the 56-60 age bracket. To see the exact nature of this anomaly, the precise ages of 1980-81 chemistry teachers need to be examined. (See Table 5) From this data, it is seen that 51 (11.6%) of the 1980-81 chemistry teachers were between 56 and 61 inclusive; 12 (2.8%) more were 62 and older; thus 63 (14.4%) of Indiana's chemistry teachers were 56 years old or older, while only 47 (10.8%) were between 47 and 55 inclusive.

Discussion

The age composition of Indiana science faculties is different than it was a decade ago and the age shift may be greater than many may have suspected. The currency of teachers' scientific knowledge and their receptivity to instructional innovations may be dramatically affected by this age shift. The implications of these side effects of increased teacher age for inservice programs presents several interesting challenges to agencies and institutions having responsibility for pro-

TABLE 5. *Tabulation of Ages of Chemistry Teachers as of December 31, 1980*

Age		23	24	25	26	27	28	29
Number		4	5	13	3	16	14	16
Age	30	31	32	33	34	35	36	37
Number	14	14	12	17	9	16	14	16
Age	38	39	40	41	42	43	44	45
Number	18	13	23	23	17	13	12	15
Age	46	47	48	49	50	51	52	53
Number	9	4	9	2	9	4	3	7
Age	54	55	56	57	58	59	60	61
Number	7	2	12	8	9	5	12	5
Age	62	63	64	65	66	67	68	69
Number	1	3	3	2	0	1	0	0
Age	70	71						
Number	1	1						
		Total 436						

viding teacher education. Most of today's science teachers have professionalized their certification; consequently, they no longer return to the college campuses for additional training. Those interested in the quality of school science instruction need to consider what effect these factors have on the flow of information into the public schools or on teacher exposure to new or innovative science curriculums.

Since one half of today's science teachers are essentially forty or older, what types of inservice programs will be attractive to them? One prominent Indiana social studies educator recently indicated he has to design programs for elementary and secondary students and get the teachers to come along as chaperones in order to secure their attendance at his inservice programs. Is the need for this arrangement a reflection of the economy as he inferred, or is it a result of an increased population of older teachers who are no longer as anxious as they once were to gain new knowledge? Even when they attend conventions and other functions where new and innovative ideas flow rather freely, are the teachers there to gather ideas which they can use to improve the science instruction or to visit with old friends?

The findings of this study definitely indicate that scientists and college science educators need to consider what kinds of programs will draw older teachers when they are contemplating how they might be of service in improving the quality of the elementary and secondary science programs.

The chemistry teacher age anomaly demands even greater attention by teacher educators. Since 14.4% of the chemistry teachers were 56 years old or older as of December 31, 1980, one-seventh of the 1980-81 chemistry teachers will have passed the traditional 66 year old retirement age by the beginning of the 1991-92 school year. This is the year when the leading edge of the new baby boom will enter the eleventh grade and take chemistry. Table 6 reports national data on live births from 1973, the year when the birth rate bottomed-out, through 1980. These data show that after stutter steps in 1974 & 1975, the birth rate began a continued upward climb in 1976. These 1976 babies entered the first grade in this fall (1981-82) and will enter the eleventh grade in the fall of 1991. If only one-fourth of them desire to take chemistry (about the current level of chemistry enrollment), will there be enough teachers to teach them?

Since it is now possible for teachers to retire early without too severe a penalty, many of the 51 chemistry teachers who are between 56 and 61 years old will be retiring in the next five years. Other younger chemistry teachers will leave the profession for more attractive positions in industry or for positions in school administration. From where is Indiana going to get the needed chemistry teacher replacements during the next decade?

TABLE 6 *Number of Live Births in U.S. Per Population Reference Bureau*

Year	Births	% Increase	% Increase over 1973
1973	3,137,000		
1974	3,160,000	0.7	0.7
1975	3,144,000	-0.5	0.2
1976	3,168,000	0.8	1.0
1977	3,327,000	5.0	6.1
1978	3,333,000	1.9	6.2
1979	3,473,000	4.2	10.7
1980	3,598,000	3.5	14.7

Is the Indiana chemistry teacher anomaly a nationwide phenomenon? In conversations with national researchers, this investigator has not been able to locate another study which has identified this specific problem; however, most published studies have dealt with broad age groups which may have masked-out this particular anomaly. Since there is a shortage of science and mathematics teachers nationwide, Indiana is not likely to obtain replacements from out-of-state chemistry teachers even if this anomaly is only a local phenomenon. Although about a dozen chemistry teachers are being prepared each year statewide, only one half of them find their way to the chemistry classroom; therefore, Indiana is not now training enough new chemistry teachers to meet its immediate needs.

What are some other possibilities? How many of the younger middle/junior high science teachers have a chemistry certification which they are not currently using? Are there similarly prepared teachers in the increased number of general science teachers? How many more of these two groups would be willing to take the additional training needed to become qualified chemistry teachers? How many RIFed [reduction in force] engineers and scientists would be willing to seek teacher certification? All of these questions need investigation. If either or both of the last two groups prove to be feasable sources from which to replenish the State's chemistry teaching force, Indiana colleges should immediately undertake the design and implementation of attractive retreading programs for these persons.

In summary, this study indicates that declining enrollments and widening differentials between teacher and industrial salaries have drastically reduced the number of young persons who have entered the science teaching profession during the last decade. The situation has now reached a point where it can dramatically affect the currency of the science instruction provided Indiana youth; a point where chemistry instruction in Indiana will soon be really hurting if something is not done almost immediately to reverse current trends.

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How to Help Students Improve Their Skills in Scientific Writing

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Today, educators are concerned about the writing skills exhibited by many high school and college students. This concern was common at the high school level twenty years ago; it may be even more common and more valid today. Because many students demonstrate little or no motivation toward academic endeavors, we must work very hard to help students improve communication skills in general and writing skills in particular.

J. J. Lagowski, in the *Journal of Chemical Education* (8), noted, "... scientists and humanists share a common concern over the deterioration of the educational processes as reflected in the well-documented decline of high school seniors' reading and writing skills since the 1960's." He also mentioned a recent national survey which reveals, "the number of remedial classes in English, both grammar and composition, and mathematics increased by 22% in colleges and universities during the 1980-81 academic year."

Technical writing, in the broadest sense, is factual, non-fictional writing. It includes writing about scientific matters for other scientific specialists. Examples may be found in *Cell Biology*, the *Journal of Heredity*, and the *Journal of Inorganic Chemistry*. This type of technical writing is called scientific writing, while science writing is that addressed to the general public. Science writing should, therefore, be less technical than scientific writing. Finally, when we speak of material written for engineers about engineering matters, we speak of technical writing in its narrowest sense.

Many scientists and engineers receive no formal instruction in scientific or technical writing at the post-secondary level. While some professionals write better than others, all can improve. Those who write better advance more rapidly in their profession. Teachers can help future scientists and engineers to do a better job of writing, but they must work at it continuously.

This problem is described very well by C. G. Enke (6) of the Department of Chemistry at Michigan State University who wrote,

> "It is difficult to overemphasize the importance of writing in the professional life of a scientist. The amount of the time my colleagues and I spend writing is out of all proportion to the fraction of our training devoted to developing writing skills. Publish or perish is a cliche, but it carries the unmistakable implication that experimental work and elegant theories have no peer value until they have been put in manuscript form. I was shocked to find that the time and effort of writing was often equal to that of the research work being described. In addition to research papers, I am continually involved in writing proposals, reports, course syllabi, laboratory experiment instructions, letters of recommendation, manuscript reviews, book reviews and books. This is the common experience of academic scientists and the tasks of writing fall heavily on industrial scientists as well."

Robert Barrass suggests, "Science teachers should help in teaching English by telling young scientists *why* they need to write and *how* they should write.

Children will not appreciate the importance of writing in all their school work if the teacher of English is the only one who corrects errors in grammar" (1). When I taught high school biology, my students often asked why I worried about their grammar because I was not an English teacher. I tried to convince my students that grammar and spelling are important in all fields. A few have since told me my efforts were helpful.

In writing about the problems faced by college instructors who stress the need for skill in written communication, Davis and Matlak (3) noted that students do not realize that they face a more rigorous review of their work in science classes than in many other disciplines. They say, "The critical, testing attitude implicit in science predisposes the science audience to attack any written work which lacks organization and clarity. Words which do not directly enhance clarity or communicate information are viewed as superfluous. In essay exams, information which was not asked for generally costs the student grade points." When this happens repeatedly, students may withdraw and learn to dislike the rigorous courses. They tend to take the path of least resistance which may haunt them and society for the rest of their lives. In an age of increasing dependence upon science, technology and communication, we can ill afford to perpetuate such a situation.

The greatest discovery in science is nothing until it has been reported to the scientific community and verified by another individual or group. Thus, communication, especially precise writing, is very important to a scientist. It is essential that the reader recognize an orderly progress "from inference to hypothesis to evidence to generalization" (10). Yet, many editors of scientific journals have observed that a great number of scientists today are in need of improved writing skills. According to DeBakey, "Only the rare scientific manuscript requires no changes at all. Minimal changes consist in making the manuscript conform to the editorial practices of the journal regarding spelling, symbols, abbreviations, hyphenation, capitalization, punctuation, nomenclature, format for citations of references, and other mechanical considerations, which may be detailed in the copy-editing manual of the journal or publisher" (5).

Also, Barrass has noted, "It is not enough to teach scientists about science. We must also help them to be effective as scientists. And there is a certain irony in teaching students of science and engineering to use techniques and instruments, some of which they may never use in their working lives, and yet not teaching them to write—the one thing that they must do every day as students, and as administrators, executives, managers, scientists and engineers" (1).

According to Justin Leonard, "The Ph.D. in science can make journal editors quite happy with plain, unadorned, eighth-grade level composition" (9), while Robert A. Day suggested, "In scientific writing, we say, the best English is that which gives the sense in the fewest short words" (4).

Some of the common errors in writing are described by Barrass (1). Only a few of those errors are treated here:

A. Terms frequently misused—

alternatively	for alternately
either	for each (or both)
except	for unless
generally	for usually
major	for great
minor	for little

several	for some
weather	for climate

B. Unnecessary qualification of words—

absolutely perfect	perfect
almost perfect	imperfect
conclusive proof	proof
few in number	few
small in size	small
quite obvious	obvious
hard evidence	evidence
raw data	data
very relevant	relevant

C. Circumlocution—

In virtually all sectors of the environment . . .	Almost everywhere . . .
I myself would hope . . .	I hope . . .
on a regular basis	regularly
It was observed in the course of the demonstration that . . .	We observed . . .

D. Lack of precision—

approximately means very closely (not about or roughly)
data (plural) refers to facts such as measurements recorded as numbers
results are obtained by the analysis of data
significant is a precise statistical term; it should not be used in other contexts
infer is what a reader or listener may do; the writer or speaker implies
comprise (not comprised of)
different from (not different to)
superior to (not superior than)

Peterson (10) noted, "The relationship of scientific logic to scientific writing is considered in terms of organization. Good organization, not only of the whole report but of all the parts, is the key in good writing." He continues, "When an author sits down to write a journal article, his first task is to visualize and construct a logical pattern or design that he can follow . . . [This design] can be made evident by the skillful use of the rhetorical techniques of outlining, paragraphing, topic sentences, and 'binding words'." Joanna Freeman noted, "Certain characteristics of effective writing are always desirable in every type of technical writing: correct grammar, punctuation and spelling, clear organization, and a direct style" (7).

Many fine sources are available to aid you and your students as you work to improve your writing skills. Some of these sources are identified in the bibliography by Cory (2).

Robert Barrass (1) suggested the following rules for effective communication:

"1. Always decide what you wish to say, why you wish to say it, and whom you hope to interest, before you start to write.

2. Write of things you know, if you have something interesting to say.

3. Plan your work so that information and ideas can be presented in a

logical and *effective* order, and so that the whole composition has the qualities of balance and unity.

4. Write for easy reading. Begin well. Keep to the point, be *clear*, direct and forceful. Maintain the momentum of your writing to the end. End effectively."

You should then revise your work two, three, or more times.

Robert A. Day (4) managing editor of the American Society for Microbiology for nineteen years and now director of ISI Press, a subsidiary of the Institute for Scientific Information, recommends you consider these four questions, in order, as you prepare a scientific paper:

1. What is the problem? (Your answer is the INTRODUCTION)
2. How did you study the problem? (Your answer is the MATERIALS AND METHODS section)
3. What did you find? (RESULTS)
4. What did your findings mean? (DISCUSSION)

Next, add a SUMMARY and list your REFERENCES (or LITERATURE CITED). Some editors prefer an ABSTRACT of about 200-250 words including principal objectives, scope of investigation, methodology, results and principal conclusions instead of a summary.

Day suggests ten points for reviewers. Writers should evaluate their writing before submitting it to a publisher in the light of these same points:

1. Importance of the subject studied
2. Originality of the work
3. Appropriateness of the experimental design
4. Adequacy of your experimental techniques
5. Soundness of your conclusions and interpretation
6. Relevance of your discussion
7. Soundness of the organization
8. Adherence to the appropriate style manual
9. Appropriateness of the title, and
10. Appropriateness for the journal to which it is being submitted.

Teachers can be most useful to students if we improve our own writing skills. But there is no short-cut to good writing. If you wish to improve as a writer, you must write, have your work evaluated, then write and write some more. You should also submit an article or a book review to a journal such as the *Journal of College Science Teaching*, *The American Biology Teacher*, *The Hoosier Science Teacher*, *The Science Teacher*, *The Physics Teacher*, or the *Journal of Chemical Education*. You will enjoy sharing your ideas with others. Such sharing can be very rewarding!

In summary, we have major deficiencies in scientific and technical writing among scientists and engineers today. As educators, we often do not prepare these people adequately for this very important aspect of their professional lives. In this article, suggestions are provided by which teachers can help students to improve their writing skills. If you feel this area is important, you should impress upon your students the importance of learning to write with clarity, precision, and economy in a style which will prove interesting to the intended audience.

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Teaching Faculty Members to Write Computer Simulations

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One of the major challenges of the 1980s will be to train college faculty members, who are not technologically oriented or who were educated before the current boom in electronics, to use computers in the classroom. Although computers have been integrated into many science, engineering, and social science courses, faculty members in the humanities and education will be faced with the need to integrate computers into their courses for the first time. Any one of a number of approaches could be choosen to teach interested faculty members to write computer simulations. One very viable approach is to hold workshops to train the faculty members to program using an authoring system. The strengths and weaknesses of this approach as well as the rationale for using it are discussed below within the historical context of their implementation at Indiana University at Kokomo. The model presented here should offer other interested faculty members useful insights into the best way to introduce their colleagues to programming and computer simulations.

Methods of Instructional Computing

There are three basic ways to use the computer as a teaching tool: 1) computer testing, 2) computer-managed instruction, and 3) computer modeling. When using the computer to administer tests, the faculty member usually has one of two objectives in mind. The computer can function either as an electronic study guide, allowing the students to assess their mastery of a specific subset of course material; or the computer can actually administer tests, record scores, and compute class averages. In either case, the programming is not complex, but it can be repetitive and tedious. Unless the only goal of the faculty member is to compile a computer test bank, this type of project is best avoided when training faculty members to program.

The best known classroom use of computers is in computer-managed instruction. Computer-managed instruction forms the basis of tutorials and drill-and-practice exercises. In a tutorial, the computer functions in the role of a tutor to lead the students through a new set of course material. In drill-and-practice, the computer is used by the students to practice a skill, such as addition or spelling. A number of fine programs already exist in these areas, and further expenditure of time would not be profitable unless the faculty member were absolutely certain of making a significant change in an already existing program or of writing a new program on a subject that had received only marginal attention.

The last method of using the computer in the classroom is through the use of computer models. Computer models are beneficial to the students because they teach problem solving. They are interesting to faculty members because they involve dynamic rather than static systems. The two types of computer models normally encountered are games and simulations. Although some games may seem frivolous, they can be beneficial to the student if they teach optimizing strategies. Pedogogically, the best use of the computer is in simulating real-world phenomena. Simulations can be used to teach concepts which involve time-consuming field testing or expensive equipment not found on an average campus. Simulations can

dramatically expand the impact of a concept in the classroom. Therefore, simulations offer the greatest possibility for improving the quality of instruction in any course.

Methods of Introducing Instructional Computing

Simulations could be introduced into the classroom in one of three ways. First, the instructors could buy the available software for their classes. Using this approach, they do not need to know how to program, but they are forced to treat only the topics included in the purchased software. Because most instructors are rarely satisfied with purchased instructional materials, they will be tempted to adopt a second approach; that is, buying and modifying the available software. However, to use this approach, the instructor must not only program, but must also be able to modify someone else's work without destroying the way the simulation functions. Depending upon the nature of the modifications, it is probably more efficient to design new software. This is where the problem comes in. Most instructors are not satisfied with purchased software, but they cannot program their own. If they are not technologically oriented, they probably will not try. A simple method of introducing computer simulations and programming, such as the use of an authoring system, is required.

Programming Skills and Programming Frills

Any programming language must be quite complex in order to carry out the diversity of functions required by the business, scientific, and educational communities. Nevertheless, an instructor does not need to master all the facets of a programming language in order to start writing simulations. Most instructors want the students to be able to input data, to manipulate the data, and to obtain the correct answers at the end of an experiment. Data input, output, and manipulation are basic programming skills. These processes lie at the heart of any successful program, but a program based solely on them would be rather dull. Most simulations are interactive. They require the establishment of a dialogue between the student and the computer. Complex tabular data are often produced. Different types of graphs, requiring the development of plotting subroutines, are also valuable. The ability to add these features to a program requires a greater knowledge of the programming language than most instructors have initially. These procedures might be called the programming frills. In the long run, a faculty member should master these frills. However, when the instructors are writing their first programs, an authoring system could be used to provide these aids.

Choice of a Programming Language

After deciding what basic programming skills the instructors should know, a programming language must be choosen. At the present time, the choice would appear to lie between using a compiler language, such as FORTRAN, or an interpreter language, such as BASIC. Three points must be considered in making this choice. First, a compiler language is harder to learn than an interpreter language. However, once a compiler language has been mastered, knowledge of the simpler interpreter languages is easy to acquire. If an instructor starts with an interpreter language, the compiler languages will remain relatively more difficult to learn. Second, the compiler language, because of its greater complexity, will allow the instructor to write more complex programs. Third, a compiler language is faster for long programs, whereas an interpreter language is excellent for short programs. Hardware capabilities are also an important consideration when dealing with program length. Interpreter languages (i.e., BASIC) and microcomputers are almost

inseparable. For long programs involving considerable amounts of data, microcomputers are either too slow or lack sufficient memory for the program to run.

Authoring Systems

Another option for teaching faculty members to write computer simulations does exist. This option, the use of an authoring system, is probably the easiest to use. If an authoring system based on FORTRAN or some other compiler language is choosen, the difficulty in learning to program will be intermediate between the difficulty of a compiler language and that of an interpreter language. The level of difficulty is not as great as for a compiler language, because the authoring system keeps the power of the compiler language while removing the burden of bookkeeping from the faculty members. Having mastered the authoring system, the faculty member can move either up or down in language complexity. EXPER SIM was the FORTRAN-based authoring system used in the simulation workshop at Indiana University at Kokomo.

EXPER SIM

EXPER SIM (short for EXPERimental SIMulation; 1) is a set of computer programs and instructional materials developed to teach research design (Figure 1). EXPER SIM requires the instructor to have some knowledge of the basic programming skills, but it provides the programming frills needed to produce a sophisticated simualtion (see above). The faculty member must provide the algorithm, the list of experimental (input and output) variables, and any applicable data base. One or a combination of three types of algorithm might be used. The most common type of algorithm is a simple mathematical equation. The second type is the data-base-and-table-look-up algorithm. The final type is the logical or true-false algorithm. EXPER SIM will handle the input and output of the data, all prompts to and responses from the students, plotting, and table preparation. In addition, EXPER SIM will provide various library subroutines, such as random number generators and integration routines. An authoring system, such as EXPER SIM, makes getting involved with programming easiem, because the more difficult tasks are performed by the system and not by the instructor.

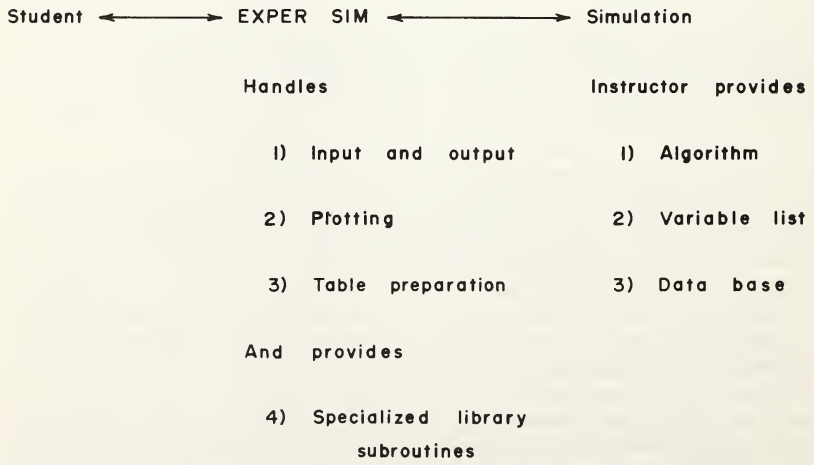

FIGURE 1. *The relationship between the student, EXPER SIM, and the instructor-generated simulation.*

Choice of Participants

Along with the goals and structure of the programming workshop, the choice of participants is crucial to the success of the project. A basic mistake is to start with a large number of faculty members and to expect to excite them for the duration of a lengthy computer workshop. Many instructors would already be using the computer if it were not for either apathy or fear. A lengthy workshop will not interest them, particularly if the workshop moves rapidly from topic to topic. The best approach is to develop computer literacy gradually over several years throughout the faculty. A minimum of two years is absolutely necessary. The best available personnel should be trained the first year. These faculty members should be comfortable handling numerical data, they should have expressed an interest in innovative teaching, and they should not be frightened by the computer. Considerable effort should be expended to train these faculty members well, to maintain their enthusiasm at a very high level, and to insure that they have functioning programs at the end of the first year of work. The dividends from this background work will come in the second year of the project. During the second year, a workshop, open to all faculty, should be held. The instructors trained during the previous year would serve as group leaders during this workshop, removing the need for the project supervisor to work with each participant. Instructors in the same disciplines might choose to work together, or the new participants might work with close friends. Dealing with enthusiastic faculty members who have experience with the system builds confidence in the new participants.

The Workshop

About 80% to 90% of the background material necessary to program and to write computer simulations should be presented in the workshop. Any special problems that deal with an individual faculty member's project should be handled when that faculty member is writing his/her own program. A minimum of six topics should be discussed in the workshop:

1) The campus computer
2) The authoring system
3) Basic programming skills
4) Debugging
5) Editing
6) File manipulation.

One or two lectures on each of these topics should be followed by having each workshop participant work through the same sample program.

The faculty members need to know how the authoring system works and how to develop suitable instructional materials to use with it. An authoring system will require that the faculty member provide the information it will use in a specific format. These requirements should be explained to the faculty members. Then, the faculty members should be required to do a literature search on the sample problem to find the required information and to convert it to the format required by the authoring system. When using EXPER SIM, a list of the input and output variables as well as the algorithm used to manipulate these variables are required. By reading a selected number of papers, the faculty members can find the input and output variables as well as the algorithm for their sample program.

Programming instruction should not center on the language itself, but on the portions of the language needed to work with the authoring system. This information can be presented in two steps. First, READ and WRITE statements, FORMAT

statements, and the mathematical manipulation of data should be covered. By combining the information obtained during the simulated literature search with these basic programming skills, a simple simulation can be constructed which can take the input variables, calculate the output variables, and package the results in a pleasing format. Once this simulation is running, arrays and plot subroutines can be added to make it more complex. The workshop leader's basic concern should be to present enough information to allow the participants to successfully complete each task while not loading them down with too many new concepts. Compartmentalization of the tasks helps the participants to complete each task successfully and, thus, keeps their enthusiasm high.

As the participants write their first program, they will make a large number of mistakes. The more mistakes they make in the controlled environment of the workshop, the better off they will be later. Editing and file manipulation should be taught as the participants write and modify their sample programs. The sample simulation actually has two functions. The first is to allow the participants to develop a positive feeling about the project by helping them write a program that runs. The second is to acquaint them with most of the mistakes they will make in writing their own programs. Because both the sample simulation and their own models will be constructed using the same format, the errors should be repetitive. The instructors should keep a card file of their error messages, the program statements that caused them, and the method used to correct them.

Program Status at Indiana University at Kokomo

The procedures outlined above are being used to teach programming at Indiana University at Kokomo. As a result of carefully screening the participants and of running a highly structured workshop, only one faculty member has choosen not to complete the program in the last two years. At the present time, six simulations have been completed and eight more are being worked on. Short summaries of the completed programs are provided below:

TEMPerature: This simulation models the variation in leaf form (margin type and size) with climate (mean annual temperature, mean annual range in temperature, and total annual precipitation) in the Western Hemisphere. The students may also make paleoclimatic predictions based on leaf form at 52 fossil localities in the western United States.

LFMARG (*LeaF MARGin*): This simulation models the variation in leaf margin type in the woody plants of Indiana. A data bank containing leaf form information for all 227 woody dicots native to Indiana was constructed. The data bank contains the scientific name of each species, its leaf characteristics (margin type as well as leaf length and width measurements), and the counties where the species has been reported growing. Leaf margin variation may be studied by county for all the woody dicots or for subsets of the data bank (for example, trees or deciduous trees). The variation may be contoured over Indiana.

LFSIZE (*LeaF SIZE*): This simulation models the variation in leaf size in the woody plants of Indiana. It makes use of the same data bank as LFMARG. Contour maps for the variation in leaf size over Indiana may be drawn from the data generated by the simulation.

CLIMATE: This simulation enables the students to study the variation in seven climatic variables at 91 weather stations in Indiana and the adjacent states of Kentucky, Illinois, Michigan, and Ohio. The climatic variation encountered may be compared with the variation in leaf form obtained using LFMARG and LFSIZE.

MARKET: This simulation models price determination in a competitive market using supply and demand equations. Graphical output is provided through EXPER SIM.

PROPagation: This simulation models the loss of signal common when transmitting between high frequency radio antennas in different climates and topographic situations. The graphical output is varied by means of a random number generator. The random number generator insures that the curves fluctuate slightly as would be the case if an actual signal were being monitored.

These models are unique. None was produced by modifying existing software. All are on specific topics which have received little or no attention from other educators. The models supplement the lecture materials in the courses where they are used.

Conclusions

By the end of the 1980s, almost all college faculty members will be required to use the computer in their classrooms. Some method will have to be provided for them to gain the necessary computer literacy. This paper suggests one possible method, based on the author's experience at Indiana University at Kokomo. The suggested approach requires the regular scheduling of workshops designed to introduce faculty members to programming and computer simulation using an authoring system. The authoring system allows the faculty members to write computer simulations without becoming bogged down in the details of a computer language. The workshop introduces the faculty members to the concepts that programming is, at its heart, an artistic process and that programs will constantly evolve over the years. A sense of adventure is instilled in the faculty which will lead them to try new programming languages and new programming techniques in the years to come.

Acknowledgment

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SOIL AND ATMOSPHERIC SCIENCES

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ABSTRACTS

Sub-Synoptic Analyses of the Severe Weather of 9/10 July 1980. R. H. Brady, J. T. Snow and D. R. Smith, Department of Geosciences, Purdue University, West Lafayette, Indiana 47907.——The development and movement of severe convection on 9/10 July 1980 in the central Midwest is related to sub-synoptic background conditions by the analysis of meteorological variables determined from an objective analysis scheme. This scheme, utilizing data from approximately 90 hourly observing stations, graphically shows the temporal and spatial evolution of temperature, pressure, and convergence fields associated with the development and intensification of several strong thunderstorms. These storms formed and moved southeastward along a well defined quasi-stationary front extending across north central Illinois and central Indiana. Very strong gradients across this front were evident in the temperature and mositure fields. An enhancement of these already significant gradients occurred during the afternoon of 9 July 1980 over northeast Illinois and northwest Indiana, the area over which the strong convection initially developed. The local intensification of these gradients appears to be a result of a combination of factors:

a. the advection of hot, moist air into central Illinois in advance of a synoptic scale frontal wave,
b. the effect of the cool waters of Lake Michigan to modify the thermal gradients, and
c. residual outflow of cool air left behind by morning thunderstorms in the vicinity.

The influence of Lake Michigan on the thermal as well as the convergence/divergence fields may have played a key role in the location of the initial convective activity. Apparent from the analysis is the development of an area of high MLCL (Modified Lifting Condensation Level) values associated with the frontal wave over Illinois and Indiana with a closed maximum located over central Indiana. This feature was detected 2½ hours prior to the development of very strong convection in this same area. An isallobaric analysis revealed that the largest pressure falls occurred in this region during this time. Differential analyses of surface potential temperature, MLCL, and covergence/divergence fields show the greatest changes in these variables also occurred 2 - 5 hours before the storms reached their peak intensity with a tornado touchdown occurring at 0235Z 10 July. Yet to be investigated is the acceleration of the frontal wave between 00Z and 01Z and its relation to the convective activity.

One interesting aspect of this study is the notable lack of convection over central Illinois, an area which appeared to be highly favorable for severe storm

development. Work continues on identifying the reason(s) why convection was suppressed in this area.

Mapping Hydric Soils of Arctic and Subarctic Wetlands Using Landsat MSS Data. STEVEN J. KRISTOF and RICHARD P. MROCZYNSKI, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana 47907.——A study was conducted to determine the feasibility of using machine-aided analysis of Landsat MSS data to inventory hydric soils of arctic and subarctic wetlands in the Canadian Arctic, especially in the MacKenzie River area. Hydric soils of these regions belong to Cryosolic soils group. They are mineral and organic soils that have permafrost 1 m from the surface in some part of the pedon or to a lithic contact. Three major Cryosolic soils with their subgroups are recognized as the Great Group:

1. Turbic mineral soils with cryoturbation (broken horizons and displaced materials) with Brunisolic, Regosolic and Gleysolic as subgroups.
2. Static mineral soils without Cryoturbation with subgroups: Brunisolic, Regosolic and Gleysolic.
3. Organic soils with organic layer greater than 40 cm thick with Fibric, Mesic and Humic and subgroups.

The vegetation associated with Cryosolic soils varies from the sparse plant cover of the Arctic, to tundra, and to subarctic and northern boreal forest.

A clustering algorithm was used to divide the satellite data into groups of sample points of similar spectral characteristics. Statistics developed on these groupings were input to a maximum likelihood algorithm. The following terrestrial and aquatic environments were discriminated: shallow lakes and ponds, drained lakebeds, sandbars, river channels, lagoons and bays, MacKenzie River water very high in suspended sediments, water of the Beaufort Sea, lagoons and lakes with medium or low amounts of suspended sediments. Separation of the mineral hydric soils from organic hydric soils was quite successful as was the separation of turbic from static mineral cryosols.

Calcium and Magnesium Relationships in *Poa pratensis* L. as Affected by NPK Fertilization on Edwards Muck. J. W. LIGHTNER, C. L. RHYKERD, D. B. MENGEL, G. E. VAN SCOYOC, E. L. HOOD and C. H. NOLLER, Department of Agronomy, Purdue University, West Lafayette, Indiana 47907.——A two-year experiment was conducted on Edwards muck (Limnic Medisaprist) on the Pinney–Purdue Agricultural Center at Wanatah, Indiana to study the effect of NPK fertilization on the Ca and Mg concentrations in bluegrass (*Poa pratensis* L.). Eight combinations of N-P-K fertilizer (0-0-0, 0-99-0, 0-0-372, 0-99-372, 168-0-0, 168-99-0, 168-0-372, 168-99-372 kg/ha), were applied each spring. Four cuttings were taken annually during the 1979 and 1980 growing seasons from a 1.5 m^2 caged area. Soil tests for pH, available P and available K for the top 30.5 cm of the soil's profile were performed.

Soil pH ranged from 4.9 - 5.9 averaged over the top 30.5 cm of the profile. Adequate levels of available P and available K were maintained in the soil throughout the study. However, the major percentage of each (62 and 67% respectively) remained in the top 7.6 cm of the soil's profile.

Averaged over both years, the Ca and Mg concentrations in the forage ranged from 0.31 to 0.64% and from 0.18 to 0.34% respectively. According to the results, 168 kg/ha of N and 99 kg/ha of P applied together increased the Ca concentration in the forage. However, when N and P were applied alone, there was a tendency for Ca levels to decrease slightly. Nitrogen fertilization increased the concentration of

Mg in bluegrass forage while concentrations of both Ca and Mg were significantly reduced by the application of 372 kg/ha of K fertilizer.

Based upon exchangeable cation data and recorded concentrations of Ca and Mg in the forage, it appears that Kentucky bluegrass is able to obtain sufficient amounts of both minerals from the Edwards muck in northern Indiana. However, the levels of Ca and Mg, in the forage tend to be lower in the first cutting, especially when K fertilizer is applied. Therefore, it may be necessary to include both these nutrients in the mineral supplement of the animal's ration, early in the growing season for some classes of cattle grazing these types of pastures.

Dissolution Rates of Agricultural Limestone Granules in Soils. A. J. OHLROGGE and SHERRY FULK-BRINGMAN, Purdue University, West Lafayette, Indiana 47907.—— Dolomitic and Oolitic agricultural limestone granules between 4.76 and 2.38 mm in diameter were mixed into the 0-5 and 5-10 cm soil depths at three locations in Indiana. Plots were established in the fall of 1980 before the first freeze and the granules were quantitatively recovered in the spring after the last freeze. Recovery ranged from 65.8% to 78.2% at the 0.5 cm depth and 79.4% to 86.0% at the 5-10 cm depth indicating dissolution rates much higher than generally accepted.

Similar granules saturated with water and subjected to 20 freeze-thaw cycles in the laboratory resulted in a recovery of 90% of the 8 mesh sieve. This decreased to 45% when a one percent methanol wetting solution was used.

The Purdue Regional Objective Analysis of the Mesoscale (PROAM) Scheme. J. T. SNOW and R. H. BRADY, Department of Geosciences, Purdue University, West Lafayette, Indiana 47907.——A simple objective analysis scheme designed to directly utilize hourly surface data as reported in the FAA 604 teletype circuit is described. Based upon earlier work by Barnes (1964, 1973), this analysis routine follows in outline several similar schemes developed at the Oklahoma University and the National Severe Storms Laboratory (eg., Inman (1970), Ruthi (1978)). This scheme was specifically designed to serve as an aid to the forecaster in predicting the onset and short term movement of strong convection in the central Midwest. Input consists of hourly surface data from approximately 120 reporting stations located in an 11 state region bordering Illinois and Indiana. Analyses of standard surface data and other parameters including moisture convergence, vorticity and MLCL (Modified Lifting Condensation Level) fields are produced within 30 minutes. The scheme has recently been modified to analyze the time differences of these same variables. Future modifications include the analyses of the surface u and v component wind fields. The output can be obtained in the form of a "printer plot" on a standard line printer and hence requires no external contouring routines; therefore any facility with a functional computer system could quickly obtain the analyzed fields.

PROAM has been operational at Purdue University for about one year. During this time, this scheme has proven invaluable in helping predict the outbreak of strong convective activity. The applicability of PROAM to three recent severe storm events will be presented.

i) 8/9 June 1981

An approaching cold front triggered intense convection over the northern sections of Illinois and Indiana. Strong convergence was noted in the affected area two hours before the occurrence of the severe weather.

ii) 13 April 1981

Heavy thunderstorms developed along a warm frontal boundary in Illinois and

northern Indiana. Strong gradients in surface equivalent potential temperature and increases in convergence were a forewarning of the severe activity to come.

iii) 29 May 1981

Strong convergence and high values of the MLCL were evident ahead of an area of developing thunderstorms over eastern Wisconsin and northern Illinois.

It is the opinion of the authors that this type of objective analysis scheme can be readily adapted for operational use in forecast offices using the AFOS computer system.

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2. _____, 1973: Mesoscale objective map analysis using weight time-series observations. NOAA Tech Memo ERL NSSL-62. 60 pp.
3. INMAN, R.L., 1970: Operational objective analysis schemes at the National Severe Storms Forecast Center. Tech Circular No. 10, National Severe Storms Laboratory, Norman, Oklahoma, 50 pp.
4. RUTHI, L.J., 1978: An evaluation of surface quantities in the short term prediction of the intensity of convective activity. M.S. Thesis, University of Oklahoma, Norman, Oklahoma, 89 pp.

TABLE 1.

PROAM	
Grid Point Spacing	44.45 km
Grid Center	40.48 N, 88.93 W
Grid Size	21 x 21
Grid Area	790.321 km^2
Total No. Possible Data Stations	241
Avg. No. Data Stations	120
Approx. Station Spacing	123.3 km

Monitoring Crops for Integrated Pest Management Using Color Infrared Photograph. G. C. STEINHARDT, J. E. YAHNER, and B. L. DELKS, Department of Agronomy, Purdue University, West Lafayette, Indiana 47907.——During the cropping season of 1981, infrared and conventional color pictures were taken from a small airplane of several fields in Montgomery County, Indiana. Three flights were taken, and the resulting photographs were interpreted using the techniques for conventional aerial photography. One advantage of color infrared photography is the ability to spot problems before they can be found by other monitoring techniques. Certain properties of the soil, such as drainage and slope, are apparent. Significant crop problems such as lodging and insect damage are also apparent. Crop conditions are more difficult to evaluate using oblique photography. This is because in oblique photographs, the rows merge together so that problem areas are difficult to identify. Future work will involve more vertical photography. It is apparent that color infrared photographs can be a very useful tool in monitoring crops.

Genesis of Silty and Clayey Material in Some Alpine Soils in The Teton Mountains, Wyoming and Idaho

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Introduction

There is some difference of opinion as to whether fine-grained soil material in alpine areas of mountain ranges in the western United States is primarily the result of in situ weathering or of deposition of eolian material from other sources. Birkeland (1) and Williams (14) consider some silt and clay-rich material in the alpine areas of the Rocky Mountains to be loess. Retzer (11) and Mahaney (8) consider such fine-grained material to be primarily the result of in situ weathering. Nimlos and McConnel (10) found large percentages of silt in surface horizons of alpine soils in Montana, but considered this to be due to overestimation by the laboratory methods used. This investigation was undertaken to help provide additional data on this subject.

Most of the Snake River Plain is southcentral and southeastern Idaho is known to be covered by a thick mantle of loess or lacustrine material with characteristics similar to loess, so it is reasonable to expect that loess may be a significant part of the soil profile in the mountains east of the plain. Blackwelder (2) observed exposures of loess twenty feet deep on the forested portion of the western slope of the Teton Mountains in southeastern Idaho and northwestern Wyoming and found that its chemical composition was similar to loesses of the Missouri and Mississippi valleys. Lewis et al. (6) in a study of the distribution of loesses in Idaho concluded that the maximum elevation of loess in the Middle Rocky Mountains Province to the east of the Snake River Plain is 2135 m. More recently, Lund et al. (7) have concluded that most of the soils on the Snake River Plain of southcentral Idaho studied by Lewis et al. (6) are of lacustrine origin with only the surficial material being of possible loessial origin.

A soil survey has been published that covers the thicker loess soils of the Teton Basin (3), but there has been little detailed investigation of the characteristics of the soils formed on the westward-dipping Paleozoic sediments on the western slope of the Teton Mountains. Much of this area is above timberline and those areas above glacial valleys were affected by periglacial processes throughout much of the Pleistocene. Are the soil materials of these surfaces partly eolian in origin? If so, what is their relationship to the thick deposits of silty material in the intermountain basins west of the range? Field work during the summer of 1973 in the vicinity of Teton Canyon, Wyoming tested the hypothesis that surface material in soils on the west slope of the Teton Mountains is primarily eolian in origin. Specifically, we hypothasized that the particle size distribution and mineralogy of the mountain surface soils would show a strong similarity to loess soils in the basin to the southwest and contrast with the residuum of the diverse bedrock lithologies upon which these soils lie.

Methods and Description of the Study Area

Soil profiles along a 50 km SW-NE transect crossing four physiographic units (basin, foothills, subalpine and alpine) were sampled (Table 1). Sample sites ranged in elevation from 3200 m near the headwaters of Teton Creek in Wyoming to 1880 m in Swan Valley, a narrow loess-filled basin crossed by the Snake River before it

TABLE 1. *Description of sample sites of soils in Teton area, Wyoming and Idaho*[1].

Site No.[5]	Depth sampled (cm)	Sand %	Silt %	Clay %	Thickness of silty material (cm)	Underlying material	Altitude (m)	Physiographic unit & hillslope position
1(A)	0-10	6.6	643.3	29.1	900 +	?	1880	basin/shoulder
(A)	900	5.5	58.8	35.7				
2(A)	3-24	6.1	60.5	33.4	440	till or outwash	1960	basin/shoulder
(A)	360-400	8.7	65.6	25.7				
3(A)	3-10	6.0	68.8	25.2	76	Quaternary tuff	2200	foothills/backslope
(D)	76-118	9.8	56.8	33.4				
4(A)	0-4	6.3	60.2	33.5	46 +	Madison Ls	2485	foothills/summit
5(B)	0-11	8.5	51.6	36.9	44	Terra rossa/ Madison Ls	2430	foothills/backslope
(D)	44-296	22.7	22.8	54.5				
6(B)	0-45	9.6	44.7	45.7	45 +	Bighorn Dolomite	2790	subalpine/summit
7(B)	0-63	14.7	44.7	40.6	63 +	Bighorn Dolomite	2825	subalpine/toeslope (sinkhole)
8(D)	surface	12.3	47.9	39.8	—	Park Shale	2750	subalpine/backslope (outcrop)
9(B)	0-35	6.2	53.5	40.3	135 +	Death Canyon Limestone	2745	subalpine/toeslope (sinkhole)
(B)	70-100	4.6	52.9	42.5				
10(A)	0-30	6.5	65.0	28.5	63 +	Death Canyon Limestone	2800	subalpine/shoulder
(A)	30-63	10.1	60.8	29.1				
11(C)	0-10	32.3	38.5	29.2	10	Granite[2]	2800	alpine/footslope
(D)	25-54	71.2	13.8	15.0				
12(A)	surface	4.7	67.9	27.4	—	—[3]	2945	alpine
13(C)	10	7.8	62.5	29.7	20	Flathead[4] Quartzite	3100	alpine/shoulder
(D)	44	30.1	42.5	27.4				
14(D)	50	46.3	34.0	19.7	—	Flathead Quartzite	3200	alpine/summit (outcrop)

[1] The following additional data is available from the authors, on request: a) detailed pedon descriptions for most sample sites, b) tables containing partiile size data for all USDA and silt fractions, percent moisture, organic matter and carbonate for 59 samples from 18 samples sites, and c) a location map for all sample sites on a USGS topographic map base scale 1: 24000

[2] Turf covered lobe of a rock glacier of Pinedale age.

[3] Silt accumulation on a snow bank.

[4] Stripe of fine material between stone stripes.

[5] Letter in parenthess indicates sample group as follows: (A) basin loess and other surface horizon poresumed to be primarily eolian in origin, (B) surface horizons reflecting mixing of colian material and residual clays, (C) surface horizons reflecting mixing of colian material and coarse-grained residuum, (D) subsurface horizon where bedrock residuum is the predominant material.

opens onto the broader Snake River Plain of southeastern Idaho. Prevailing winds in the area are from the southwest and the Swan Valley site lies upwind from the alpine study area.

The physiographic units were separated on the basis of topography and vegetation (Figure 1). The basin unit (1830-1980 m) is characterized by rolling topography and a thick mantle of loess. Sagebrush is the dominant natural vegetation. In the drier parts of the basin unit soils formed in the loess are Cryoborolls with cambic horizons. The foothills unit (1980-2440 m) lies on the broad dipslope of the Mississippian-age Madison Limestone. Valleys in this unit are generally filled with glacial deposits of Bull Lake and Pinedale age. Small areas of Quaternary tuff also are present. The natural vegetation is fir and pine on north-facing slopes and sagebrush and mountain mahogany on south-facing slopes. Precipitation is greater on the foothills unit and the soils usually have argillic horizons with Cryoborolls under sagebrush-grass vegetation and Cryoboralfs under forest vegetation. Soils on glacial moraines are Cryochrepts formed under coniferous forests. The subalpine unit (2440-2800 m) lies mainly on karst benches of the ordovician Bighorn Dolomite and Cambrian Death Canyon Limestone. Stands of spruce, fir and pine exist in protected parts of the benches, but sparsely vegetated areas of limestone rubble and sinkholes predominate. The alpine unit (2800-3365 m) lies on the dip slope of the Cambrian Flathead Quartzite. Pre-Cambrian gneisses and granites are exposed in cirques and major valley bottoms. Alpine meadows, bogs and tundra predominate. Frost features such as stone stripes are common. Soils with thin cambic horizons can be found in the alpine and subalpine areas, but usually there is no evidence of pedogenic weathering. A horizons are also commonly absent in these areas.

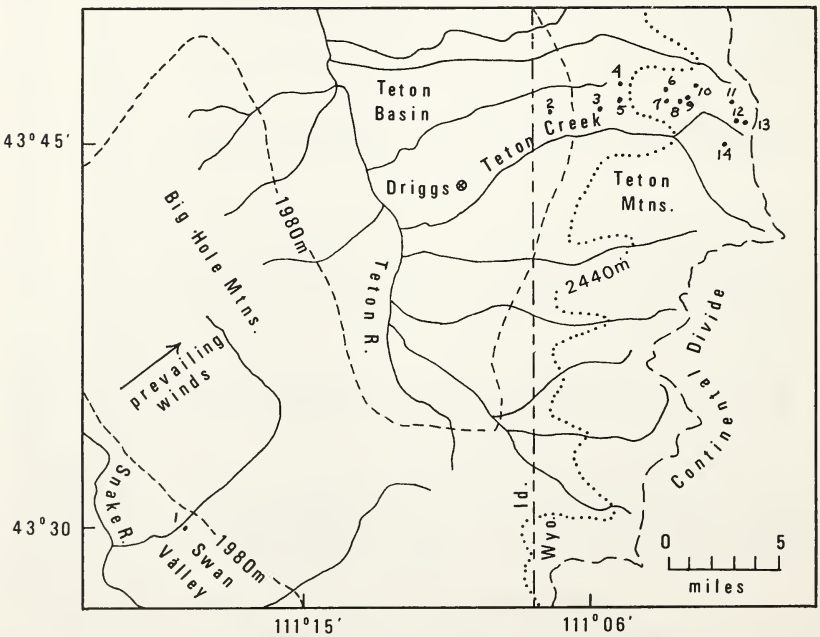

FIGURE 1. *Physiographic units and sample locations, Teton area, Wyoming and Idaho. Dashed line indicates boundary between basin and foothills units; dotted line is the boundary between the foothills and subalpine units.*

A complete profile description was made at most sample sites (see footnote 1, Table 1). The A horizon (or upper 10 cm when no A horizon was present), B horizon (generally present only in the basin and foothills units) and, wherever possible, C horizons formed in material weathered from the underlying bedrock were sampled. In the subalpine and alpine areas often no horizonization was evident in the silty material (sites 6,7,9,10 and 13), so arbitrary sampling depths were chosen.

Particle size distribution was determined by sedimentation methods developed by Kilmer and Alexander (5). Heavy mineral separates of very fine sand (100 to 250 microns) from selected samples were mounted on slides using balsalm and were studied with the aid of a petrographic microscope. Identification and tabulation of heavy minerals followed the techniques and mineral descriptions outlined by Milner (9). Calculation of mineral percentages was based on counts of 200 to 400 grains (Table 2).

Clay mineralogy was determined on selected samples by x-ray diffraction with Cu target at the Department of Geology, University of Wisconsin-Madison (Table 2). Samples were prepared by mounting a slurry of the less than 2 micron fraction on warm porcelain tiles using an eyedropper. Quantitative analysis of the relative amounts of different minerals in the clay fraction was not attempted.

Results and Discussion

The surface and C horizons of the soils sampled along the transect are dominated by silt and clay (Figure 2). For comparison, Retzer's (11) data for A and C horizons over similar parent materials (limestone, shale, quartzite and granite) in the Colorado alpine are also plotted. The contrast is striking. The soil surface material seems to fall into two distinct classes in terms of particle size distribution. The first group (Figure 3a) has curves that compare well in terms of shape with the midwestern Roxana loess but contain significantly higher percentages of clay.

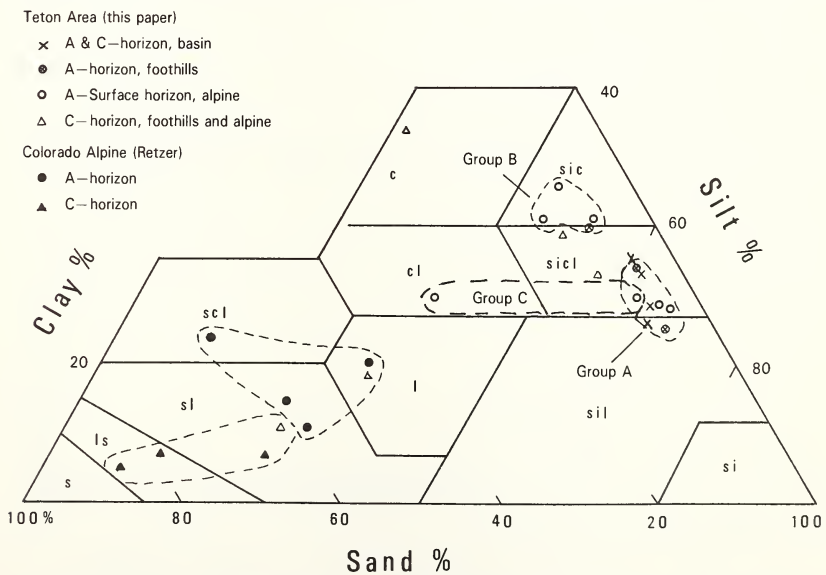

FIGURE 2. *USDA texture classes of surface and C horizons of soils in the Teton area, Wyoming and Idaho, and the Colorado alpine. Colorado data from Retzer (9).*

TABLE 2. *Heavy mineral percentages of surface horizons (silty cover) and C horizons (residuum) of very fine sand fraction (100-250 microns) from soils in the Teton area, Wyoming and Idaho.*

Site number		Mineral percentage (100-250 micron)														clay minerals (x = present)				
Silty material	Province	Muscovite	Zircon	Tourmaline	Garnet	Biotite	Apatite	Epidote	Hornblende	Augite	Hypersthene	Enstatite	Tremolite	Unidentified weathering products and colloidal material	Others	No. grains counted	Smectite	Vermiculite	Illite	Kaolinite
1	basin	5	3	8	–	6	–	–	21	22	10	3	–	11	11	316	–	–	–	–
2	basin	4	6	12	4	2	–	–	10	12	25	–	3	10	12	358	x	x	x	x
3	foothills	2	6	12	4	1	–	2	13	18	21	–	6	5	10	468	–	–	–	–
4	foothills	5	4	6	–	2	–	–	16	29	14	–	–	13	11	300	x	x	x	x
5	foothills	5	5	7	3	2	–	3	21	18	11	5	–	10	9	301	x	x	x	x
6	subalpine	6	5	9	–	2	–	–	19	21	13	–	2	18	5	187	x		x	x
10	alpine	2	5	12	1	–	4	–	17	22	18	–	3	5	11	317	x		x	x
12	alpine	12	2	5	3	16	–	–	13	6	21	1	–	14	7	240	x	x	x	x
13	alpine	12	7	7	–	9	–	–	19	9	11	1	–	19	6	299	x	x	x	x
Residuum	Lithology																			
3	tuff	26	2	7	–	33	–	–	15	–	–	–	8	–	9	749	x		x	
5	limestone	4	14	5	2	–	–	–	–	–	–	7	–	61	7	257	x		x	x
8	shale	43	–	3	–	23	–	–	2	2	4	–	–	22	1	205			x	
14	quartzite	29	4	4	–	21	–	–	7	4	3	–	–	27	1	345	x		x	x

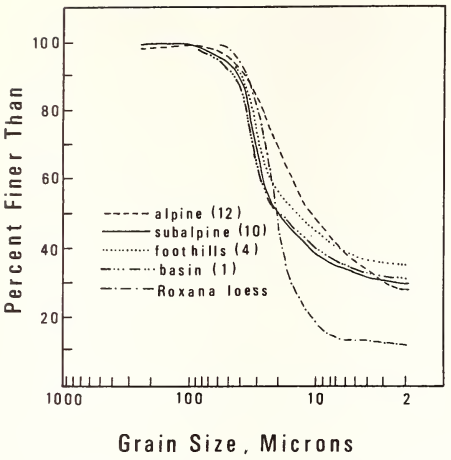

FIGURE 3a. *Cumulative particle size distribution curves of some surface horizons in the Teton area, Wyoming and Idaho compared with the Roxana loess in the Midwest.*

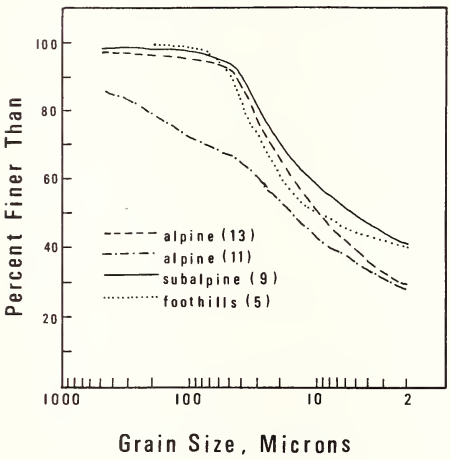

FIGURE 3b. *Cumulative particle size distribution curves of surface horizons of soils in the Teton area, Wyoming and Idaho, where loess has been mixed with residual material.*

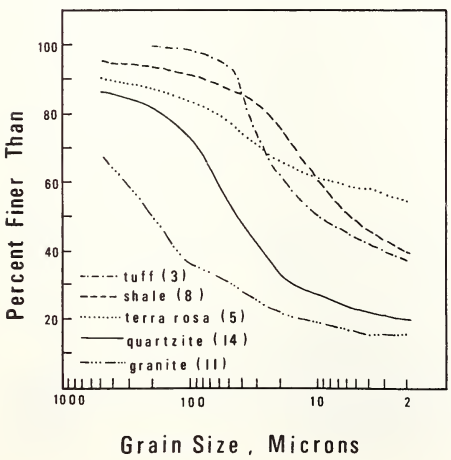

FIGURE 3c. *Cumulative particle size distribution curves of C horizons formed in residual material in the Teton area, Wyoming and Idaho.*

Samples of surface horizons from all physiographic units fall in this group and this material is presumed to be eolian in origin (Group A samples in Table 1). The second group (Figure 3b) generally has a higher percentage of clay than the first group, but also has more coarse material (Group B and C samples in Table 1). Samples from this group do not show pure loess curves and are presumed to be the result of mixing of loess with local bedrock material. This is particularly evident in sample 11, which was collected near the base of a rock glacier of granitic lithology. Only the basin soils do not have samples with this characteristic probably because loess is too thick for any mixing with bedrock material to occur. The C horizons formed in the bedrock residuum have a wide range of particle size distributions (Figure 3c), reflecting the diversity of lithology sampled.

Composition of the heavy mineral separates is quite uniform between surface horizons in the four physiographic units and contrasts strongly with the mineralogy of the residuum samples (Figure 4 and Table 2). Combined percentages of the less resistant minerals hornblende, augite and hypersthene in the loess range from 39 to 59 percent, a strong contrast to the 0 to 15 percent found in the residuum samples. In the residuum there is no significant enrichment of the resistant minerals zircon and tourmaline (3-19% in residuum vs. 7-18% in the loess), but percentages of muscovite and weathering products are much higher. Slightly lower percentages of less resistant and slightly higher percentages of more resistant minerals in the alpine samples (12 and 13) indicate that some mixing with local material has occurred.

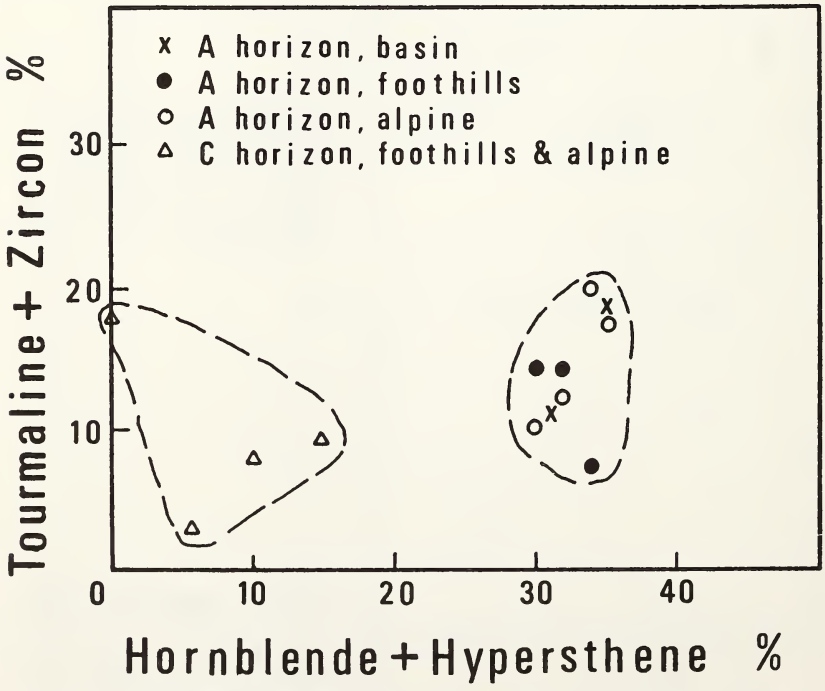

FIGURE 4. *Relationship of selected resistant to nonresistant minerals in the very fine sand fraction in surface and C horizons of soils in the Teton area, Wyoming and Idaho.*

The surface horizons of soils in all four physiographic units contain the clay minerals smectite, vermiculite, illite and kaolinite, except sites 6 and 10, which lack vermiculite (Table 2). In contrast, none of the four residual samples contained vermiculite. The sample of tuff also contained no kaolinite and the shale contained only illite. The clay mineral assemblage of the A horizons of sites 6 and 10 are similar to the terra rossa. The sample of material weathered from the Flathead Quartzite contains a much larger percentage of clay (19.7%) than would be expected. The clay minerals in this fraction are also similar to the terra rossa, suggesting that locally derived residual clays from the Madison Limestone are an important source of clays in soils over other geologic units. The large amount of fine material in the sample that was considered to be primarily weathered quartzite indicates that eolian material may be present even when it is not obvious in the field.

It is interesting to note that there is a rapid decrease in the maximum thickness of silty material between the basin and foothills units, but no significant decrease between the foothills and subalpine units (Table 1). Large rock fragments are common at the surface in the alpine tundra and on the subalpine benches underlain by limestone, but when excavated, they are found to lie in a matrix of silty material that may extend deeper than 63 cm (maximum reach of the longest armed investigator). These thicknesses of silty material do not support the conclusion of Lewis et al. (6) that the maximum elevation reached by loesses from the Snake River Plan is 2135 m. Site 12, which is silty material collected from a snowbank is at an elevation of 2945 m. Maximum thicknesses of silty material (in excess of 135 cm) on the subalpine shelves are in sinkholes which have apparently been filled by alluvial action. Soils formed in material that has been transported by water (sites 7 and 9) should be considered alluvial rather than loessial, but most of the alluvial material was probably blown to the area from a more distant source, and then moved short distances by alluvial processes.

The silty soils cluster into two groups based on clay content and a third group based on sand content and particle size distribution (Figure 2). In group A, clay content ranges from 26 to 34 percent. This groups includes samples from all physiographic units. In group B clay content ranges from 40 to 46 percent clay, and all lie on limestone. In this group, material from sites 7 and 9, located in sinkholes had been transported by water. It is likely that residual clays from local shales and terra rosa had been washed in as well. The sample from site 5 was on the east-facing backslope of the Madison Limestone and residual clay could have been worked into the profile by overwash and/or creep. Site 6 is in a summit position on the shelf formed by the Bighorn Dolomite and the mix of clay minerals is simlar to the terra rosa (Table 2) suggesting that it may have received clay washed or blown down from the Madison Limestone which rises above the Bighorn shelf in a sheer cliff several hundred feet high. The group C soils (sites 11 and 13) show mixing of eolian material with coarse-grained bedrock lithologies (granite and quartzite). Site 13 has by far the lowest silt content of the surface soil samples (38.5 percent) but this is still much higher than the residual material in the same profile (13.8 percent). Site 12 is interesting in that it appears to fall within group A based on relative percentages of silt, sand and clay (see Figure 2), but the particle size distribution curve (Figure 3b) shows that the silts tend to be coarser and do not form a loess-shaped curve.

The percentage of fine-grained material derived from eolian sources at the soil surface may exceed 80 percent, if we assume that the clay enrichment in group B (Figure 1) is solely from residual clays. Generally the fine-grained material that is eolian in origin decreases with depth. However, in some areas underlain by lime-

stone, mixing is so thorough that there is no discernable change throughout the profile.

If a significant portion of the silts and clays in the soils on the western slope of the Teton Mountains are eolian in origin, as the preceding data suggests, the question remains, what is the source and age of this material? The clay content of the fine-grained material in the study area ranges from 25 to 46 percent, which is much higher than is typical for midwestern loesses. Deep less soils in Indiana, for example, commonly have from 12 to 16 percent clay in the A2 horizon (12). Glenn et al. (Agronomy Abstracts, 1976, p.160), in a study of loess deposits and soils of the Snake and tributary river valleys in western Wyoming and eastern Idaho concluded that local floodplains are the major sources of loess in the area. The high clay content of the local alluvium probably comes from two sources: 1) terra rossa eroded from the dip-slope of the Madison Limestone and 2) ash from volcanic activity, pervalant in the area throughout the Pleistocene.

Studies in other areas have found that the very fine sand and fine silt fraction of loess decreases with distance from source (see, for example, Souster et al. (13) for the Swift Current area of Saskatchewan). Lund et al. (7) point to the lack of consistent changes in texture with distance from the Snake River as evidence that fine-grained material in the Kimberly-Stricker Butte area, Twin Falls County, Idaho, is primarily lacustrine rather than loessial in origin. This area is 200 miles southwest of the Teton study area and a review of the basin soil profile descriptions and the Teton area soil survey (3) indicates that a reinterpretation of these soils in light of the findings of Lund et al. (7) is probably unnecessary. The faint bedding on soil profiles observed in Twin Falls County was not evident in the nine meter road cut at site number 1 in the Teton study area, and the generally steeper slopes of soils described in the soil survey as loessial (mostly greater than 4 percent) compared to the Twin Falls County study area (mostly less than 4 percent) also indicates that a lacustrine origin is unlikely. Unfortunately, not enough samples of the basin loesses were taken to determine whether there were trends in particle size distribution with distance from the Teton River.

Eolian silts and clays seem to be the major source of fine-grained material found in soils above timberline, but the only "pure" loess (site 12) found in the alpine was deposited on a snowbank near the Continental Divide. This is because frost churning, rock creep and transport by water are important proccesses affecting soil development in the subalpine and alpine areas of the Teton Mountains. After loess is deposited on the surface it is continually reworked and mixed with bedrock material. Loess deposited on limestone is often tranported to sinkholes with some mixing with residual clays. Frost churning also moves loess vertically in the soil profile filling in spaces between limestone fragments to depths deeper than 63 cm. In alpine areas on the Flathead Quartzite the loess is segregated into bands between stone stripes and mixed with coarser material formed by periglacial processes. Loess deposited on rock glacier debris becomes mixed with coarser material by frost churning and rock creep.

The genesis of the alpine soils is further complicated by evidence that fine-grained material is transported by wind within the study area. As discussed earlier, the clays in the sample of quartzite residuum are similar mineralogically to the terra rossa and wind is the only likely method of transport, since the site is located on the summit of a ridge. As a consequence, the term "loessial" should probably be used with caution when describing alpine soils in the Tetons, even though most of the silty material has probably been transported by wind from outside the area.

The presence of dirty snow banks in the alpine areas provides clear evidence that deposition of loess is an active process today. The thickness of silty material over glacial tills of Pinedale age (late Wisconsin) was observed to range between 16 and 22 cm in the study area. At a site that lies above the maximum height of Pinedale glaciation (not listed in Table 1) 62 cm of silty material with an argillic horizon covers a well developed paleosol formed in an additional 122 cm of silty material over Bull Lake Glacial till (early Wisconsin). At site 4 silty material 76 cm thick with an argillic horizon lies on top of a paleosol formed in additional silty material and Quaternary tuff. The paleosol was interpreted to be the same age as found in the Bull Lake till.

The Bull Lake till and Quaternary tuff are above the part of the valley affected by Pinedale glaciation, and it appears the accumulation of eolian material in the foothills since the soil-forming period of the Bull Lake-Pinedale interglacial has been on the order of 60 to 80 cm. These thicknesses are similar to the maximum thickness of loess observed in the alpine area. These observations are consistent with the conclusions of Fryxell (4) that deposition of loess around Jackson Hole Wyoming, east of the study area, probably began immediately following the withdrawal of Bull Lake glaciers.

Summary

Fine-grained materials in the surface horizons of soils in the alpine areas of the Teton Mountains are predominantly eolian in origin. Two lines of evidence support this conclusion: 1) particle size distribution and mineral composition of the very fine sand and clay fractions of the alpine soils sampled are very similar to those of soils sampled upwind in areas which are known to be loess, and 2) particle size and mineralogy of the surface material is distinctly different from that of the material weathered from the bedrock over which the soils lie. There has been some mixing of loess with residual materials by water and frost action, but the contribution of residuum to the overlying fine-grained material of the soil profile is relatively minor, except in the case of residual clays from limestone. No definite conclusion can be made from the available data regarding the source of the loess in the alpine areas, but most of the material has been deposited since the end of the Bull Lake (late Wisconsin) glaciation.

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Estimating Solar Radiation Received on a Horizontal Surface

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Introduction

The use of daily solar radiation in climate and crop growth models and for planning active and passive solar energy systems requires an accurate assessment of the spatial distribution of daily solar radiation. Incident solar radiation is measured with pyranometers at relatively few stations in the U.S. Sunshine duration is measured at most 24-hour National Weather Service (NWS) stations, which has led to many studies on the use of percent possible sunshine to predict the incident solar radiation. Baker and Haines (1969) reviewed this literature and computed statistical regressions of solar radiation on percent possible sunshine for all NWS stations in the North Central U. S. for which both solar radiation and sunshine duration were measured. The equations were of the form

$$SR = R^*(a + bS) \qquad [1]$$

where SR is the estimated daily solar radiation at the earth's surface, R* is the extraterrestrial radiation, S is the percentage of possible sunshine, and a and b are fitted regression coefficients determined for each climatological week for the period of record, generally 1952-1966. For Indianapolis, their regression equations were generally associated with about 0.7 to 0.9 of the variance in daily solar radiation within weekly periods for which the regression coefficients were estimated.

Over the past few years models based on standard meteorological data have been proposed to simulate radiative transfer through clear and cloudy atmospheres (Atwater and Ball 1981; Davies, Schertzer and Nunez 1975; Suckling and Hay, 1977). Clear sky radiation estimates are generally within 5% of the measured values. Cloud effects are included by using a transmittance function presented by Manabe and Strickler (1964). To use this function the reported cloud type and amount are required. Considerable work is underway attempting to estimate daily solar radiation at the surface from satellite data. Encouraging results were obtained by Gautier, Diak and Masse (1980) and by Brakke and Kanemasu (1981) for both clear sky and cloudy conditions.

The objective of this study is to examine and develop methods for estimating daily totals of SR in near real time over Indiana, utilizing available information for percent possible sunshine, total opaque cloudiness, and observations of cloud heights and amounts reported hourly for aviation purposes.

Data and Procedures

There are two fairly long records of SR observations in Indiana. The NWS station at Indianapolis International Airport began in 1952 and has continued, with sizeable breaks in the records, to the present. Sunshine duration measurements and cloud observations are also taken at the same location. An Eppley pyranometer was installed at the cooperative NWS-Purdue University climatological station at the Agronomy Farm, 6 miles NW of West Lafayette, in 1957. This record of daily SR has large gaps until 1968, after which hourly solar radiation and also duration of sunshine have been measured continuously. There were no cloud observations at the Agronomy Farm, but these are taken at the

Federal Aviation Administration (FAA) station at the Purdue University Airport, about 5 miles SE of the Agronomy Farm. Sunshine duration is measured only at two other locations in Indiana, the NWS airport stations at Fort Wayne and Evansville. Cloud observations are also taken at these stations and also at Muncie, South Bend, Terre Haute, Bloomington, and Grissom AFB. At each of these stations, observations of the tenths of total and total opaque sky cover are taken, as well as the tenths of clouds at low, middle and high levels.

Three methods for estimating SR were examined and compared for their relative accuracy: (1) using percent of possible sunshine, (2) using the total opaque cloudiness, and (3) using the cloud amounts reported at each level with estimated transmission coefficients. For (1) the regression model in Eq. 1, with measurements of S and the coefficients estimated by Baker and Haines (1969), was used to estimate the SR for independent periods of record. The year 1968 was selected because solar radiation measurements were available at both Indianapolis and West Lafayette 6 NW. For (2), preliminary analysis showed that the total opaque sky cover was better correlated with SR than was the total sky cover. A day with high thin cirrostratus overcast may cause only slight diminution of the solar radiation but a heavy overcast will greatly reduce SR. Only total cloudiness is published in local Climatological Data for NWS staitons, and neither total nor total opaque cloudiness is sent in the hourly aviation reports. One has to use manuscript hourly observational forms to obtain hourly opaque cloudiness (OC) data. Since 10 tenths (overcast) OC will cause greater SR reduction during noon hours than during morning or evening hours, a daily weighted average opaque cloudiness ($\overline{OC}$) was computed by weighting the OC for each hour by the ratio of the SR for the respective hour (i) to the total daily SR received on a clear day,

$$\overline{OC} = \sum_{i=5AM}^{9PM} (SR_i/SR_{day})OC_i \qquad [2]$$

Scatter diagrams of SR on $\overline{OC}$ showed a curvilinear pattern (Figure 2) and quadratic regressions were fitted. The regressions of SR on $\overline{OC}$, as well as the SR_i/SR_{day} weights used in [2], were computed for calendar periods with similar solar declination.

For method (3) the equation used to compute irradiance (I) at the surface is

$$I = I_o \cos\theta T_R T_g T_w T_a T_c (1 + r_s r_c) \qquad [3]$$

where I_o is the solar constant, θ the zenith angle, T the transmittance after Rayleigh scattering (R), absorption by permanent gases (g) and water vapor (w), absorption and scattering by aerosols (a), and absorption and reflectance from clouds (c). The albedo coefficients in [3], r_s and r_c, correspond to a single reflectance from the earth's surface and cloud cover, respectively. The rate at which solar radiation is received outside the earth's atmosphere on a surface normal to the incident radiation (extraterrestial radiation) varies slightly throughout the year and is given by

$$I_o = 1353\ W/m^2 [1 + 0.034 \cos [2\pi(n - 1)/365)]$$

where n is the Julian day.

An empirical relationship to account for the effects of Rayleigh scattering and absorption by permanent gases was given by Kondratyev (1969). Atwater and Brown (1974) later modified this expression to account for the isotropic nature of

Rayleigh scattering with one-half of the scattered radiation being in the forward direction. This formula is given by

$$T_R T_g = 1.021 - 0.084 [m (949 p \times 10^{-5} + 0.051)]^{1/2}$$

where p is the surface pressure in kPa, and m is the air mass thickness coefficient, given by

$$m = 35/(1224 \cos^2 \theta + 1)^{1/2}$$

A formula by McDonald (1960) is used to account for water vapor absorption. The expression is

$$T_w = 1 - 0.077(um)^{0.3}$$

where u is the precipitable water and m again is the air mass. An empirical relationship by Smith (1966), used to estimate the precipitable water (u) from the surface dew point temperature (T_d), is $u = \exp[(0.1133 - 1n(\lambda + 1)) + 0.0393\ T_d]$, where λ is an empirically-derived constant for different seasons and latitudes. Since standard meteorological observations cannot be used to estimate the aerosol attenuation, T_a was evaluated as a residual from clear sky conditions. The relation follows an expression given by Houghton (1954) which is

$$T_a = 0.95^m.$$

The transmittance function used by Manabe and Strickler (1964) for multiple cloud layers is

$$T_c = \prod_{j=1}^{n} [1 - (1 - t_j)C_j], \qquad [4]$$

where n is the number of cloud layers, t_j the transmission for the jth cloud layer, and C_j the coverage of the jth layer.

The cloud transmission coefficients were estimated empirically by substituting [4] in [3] and solving for t_j for single cloud layers at various heights and coverages. Hourly solar radiation values taken at the Purdue Agronomy Farm were used in conjunction with the corresponding hourly cloud observations from the Purdue Airport FAA station, approximately 5 miles SE of the Agronomy Farm. Populations of transmission coefficients were generated for various cloud heights and coverages. The frequency distributions were fitted with a beta distribution (Yao, 1969), but only means of each distribution were used in [4] to calculate the hourly incident solar radiation. The hourly values were then summed to obtain daily SR estimates.

Results and Discussion

The daily SR values predicted with S and regression coefficients from Baker and Haines (1969) in [1], have been plotted against the respective measured SR in Figure 1 for Indianapolis. This and other tests for Lafayette and Indianapolis yielded coefficients of determination (r^2) near or above 0.9 with regression slopes near 1.

A plot of the measured SR on the daily $\overline{OC}$, computed with [2], is shown in Figure 2 for the period 15 May to 24 July, 1968, roughly a month before to a month after the summer solstice. The fitted quadratic regression was associated with 0.9 of the variance in the measured SR. The fitted regressions for other intervals of the growing season with similar declination are shown in Figure 3. Almost all of these regressions were associated with 0.9 or more of the variance in daily SR.

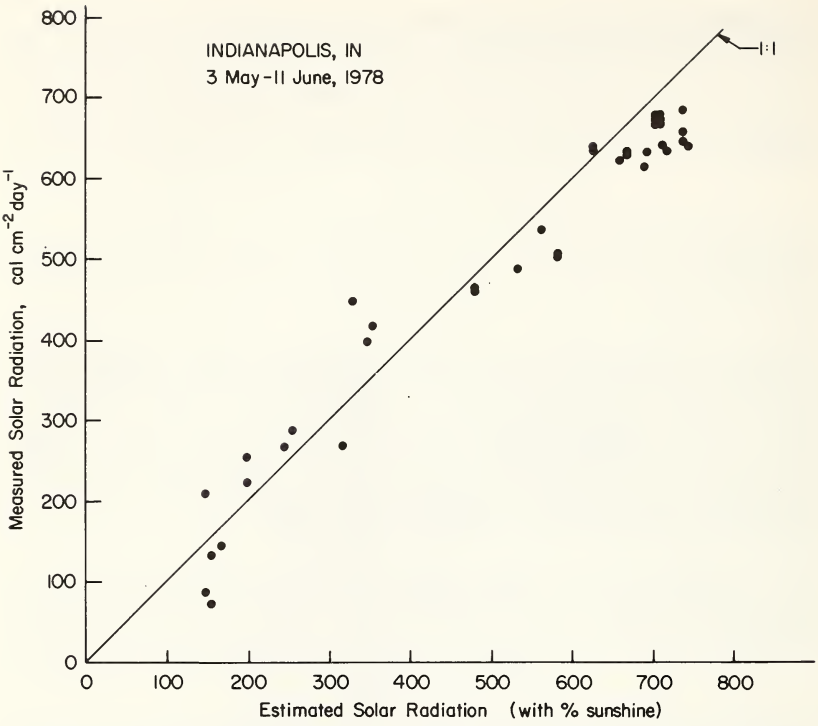

FIGURE 1. *Scatter diagram of measured daily solar radiation on that predicted with percentage possible sunshine and the regression equation from Baker and Haines (1969) for Indianapolis, IN, 3 May—11 June, 1978.*

Since the third method is more deterministic and includes more variables, some additional description of the procedural results is included. For example, a histogram of the transmission coefficients, t_i, calculated for cirrus layers (cloud heights greater than 18,000 ft.) is shown in Figure 4. The negatively-skewed distribution has a mean t_i of 0.67. Histograms were also plotted for the other cloud layers, and each was fitted with the Beta distribution (Yao, 1969). The means of the empirical distributions for the corresponding cloud layers used in [4] are shown in Table 1. Note that thin cirrus has a mean transmission of 0.81. An independent test

TABLE 1. *Means of the cloud transmission coefficient (t) for the different cloud layer heights and overcast (ovc), broken (bkn), or scattered (sct) sky conditions.*

Cloud Layer		
Height (thousands ft.)	Coverage	t
0- 6	(ovc)	.30
0- 6	(bkn, sct)	.68
6-12	(ovc)	.43
6-12	(bkn, sct)	.67
12-18	(bkn, sct, ovc)	.44
>18	(bkn, sct, ovc)	.67
"thin" >18	(bkn, sct, ovc)	.81

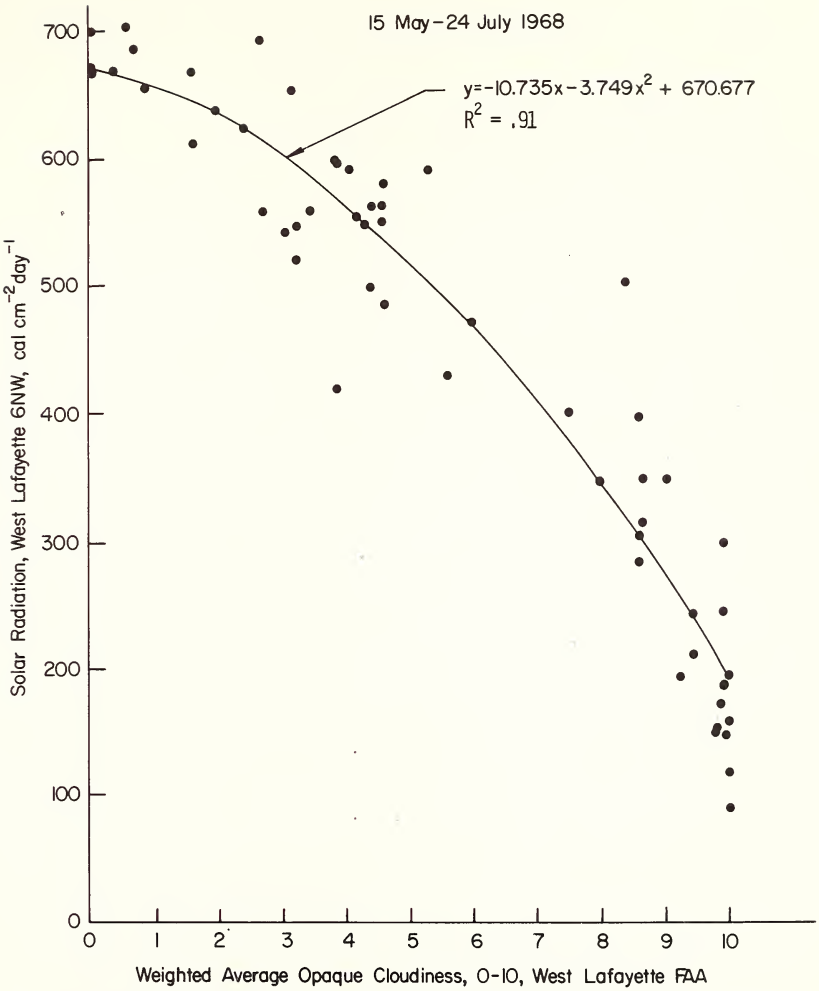

FIGURE 2. *Scatter diagram of measured daily solar radiation on weighted opaque cloudiness, West Lafayette, IN, 15 May—24 July 1968, with fitted quadratic regression.*

on 60 days randomly selected from Indianapolis in 1980 showed excellent agreement between the predicted and observed solar radiation, as shown in Figure 5. Similar results were obtained for a 120-day sample for West Lafayette, 1976 (Figure 6). Both high and low values of daily solar radiation were estimated well with a root mean square error of 1.88 MJ m^{-2} day^{-1} (45 cal cm^{-2} day^{-1}) for Indianapolis and 1.38 (33) for West Lafayette.

All three methods were tested and compared for a sample of 60 days for West Lafayette, 1976. Five days were selected from each month to give a representative sample. The mean absolute error, mean error, and root mean square error were computed for each method and are given in Table 2. The largest mean absolute

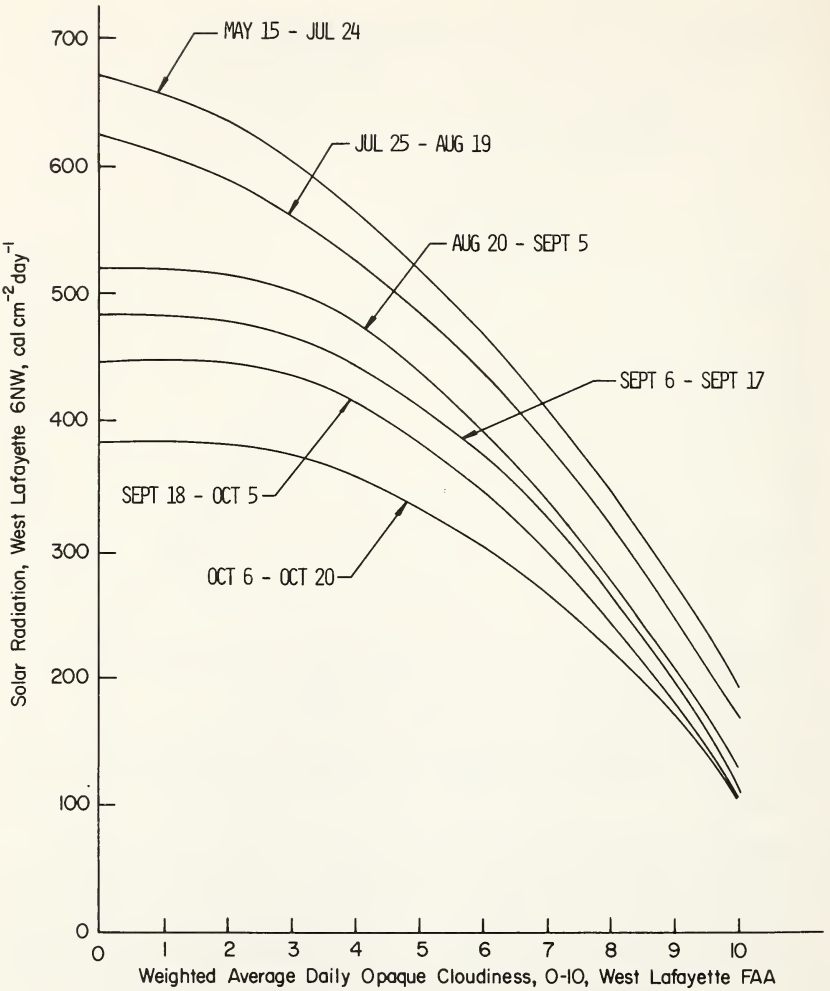

FIGURE 3. *Fitted regression equations (as in Fig. 2) for indicated period of similar solar declination, West Lafayette, IN, 1968.*

error was 2.19 MJ m^{-2} (52.4 cal cm^{-2}) per day for the first method (using percent possible sunshine). The weighted average opaque cloudiness yielded a mean absolute error of 1.5 MJ m^{-2} day^{-1}. The third method did the best, giving a mean absolute error of 1.06 MJ m^{-2} day^{-1} (25.4 cal cm^{-2} day^{-1}). The root mean square error with method 1 was the largest (2.64 MJ m^{-2} day^{-1}) and with method 3 the lowest (1.4 MJ m^{-2} day^{-1}). The mean errors for all methods approached zero, indicating all are unbiased. SR in Indiana can be estimated generally within 2.0 MJ m^{-2} day^{-1}.

Summary

All three methods presented were shown to be effective in estimating daily solar radiation for agriculture and energy-related purposes. Predictions with all

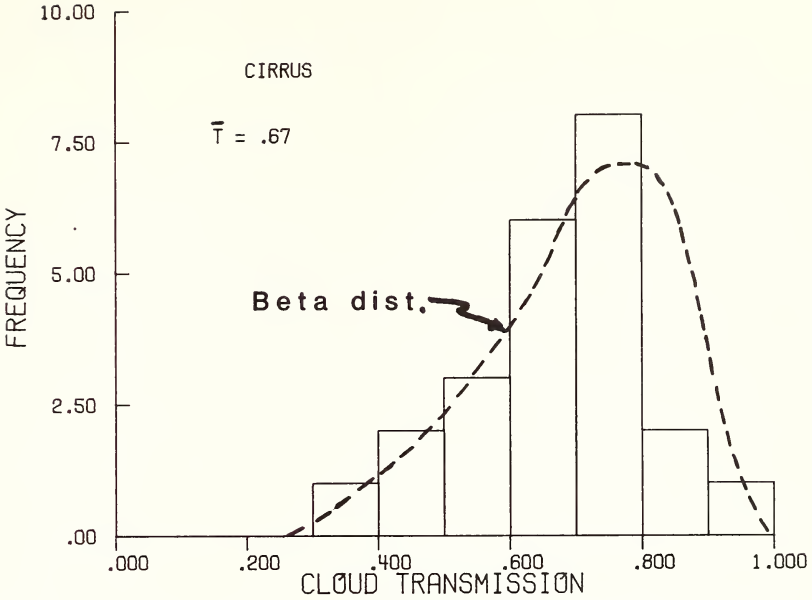

FIGURE 4. *Histogram of solar radiation transmission coefficients for cirrus clouds, West Lafayette, IN 1970-1975.*

three methods generally were with 2.0 MJ m^{-1} day^{-1} of the measured daily solar radiation. since it is unlikely that the present radiation network will be increased, cloud observations can be utilized to estimate daily solar radiation, at several additional locations in Indiana for which SR data are not available.

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TABLE 2. *Mean error* $\left(\bar{e} = \left| \sum_{i=1}^{n} \textit{predicted SR - observed SR} \right| /n\right)$, *mean absolute error* ($|\bar{e}|$), *and root mean square error* ($\sqrt{e^2}/n$) *for three methods of estimating solar radiation using (1) daily percent possible sunshine, (2) weighted daily opaque cloudiness, and (3) hourly reports of cloud heights and amounts for five days in each month, January-December, 1976, West Lafayette, IN.*

Method	Mean error	Mean absolute error MJ m^{-2} day^{-1} (cal cm^{-2} day^{-1})	Root mean square error
1	-0.38(-9.04)	2.19(52.4)	2.64(63.2)
2	-0.18(-4.20)	1.45(34.6)	1.98(47.5)
3	-0.16(-3.80)	1.06(25.4)	1.38(33.1)

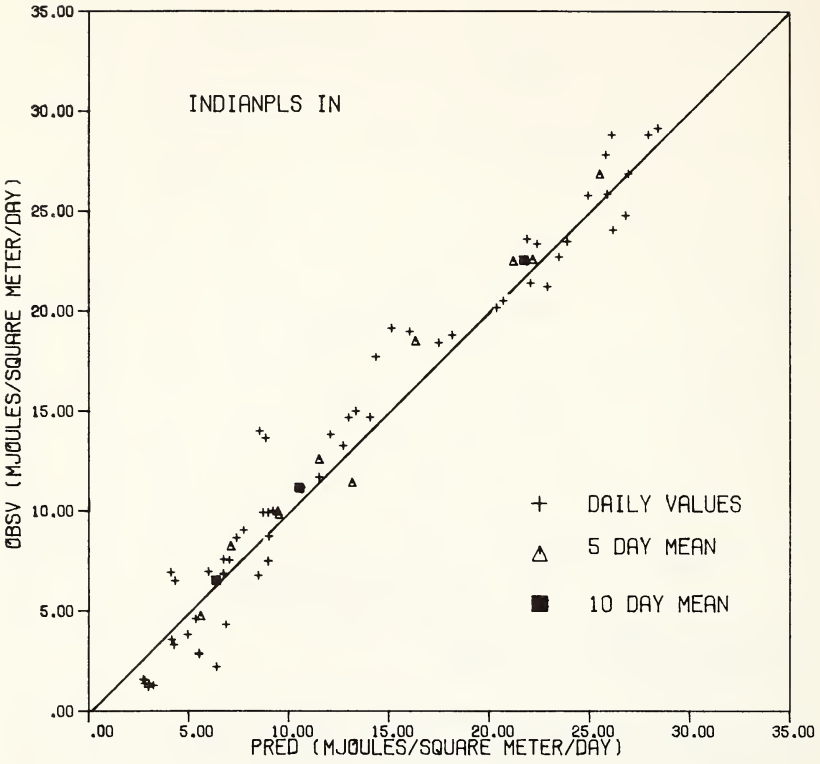

FIGURE 5. *Scatter diagram of measured daily solar radiation on that predicted with hourly cloud amounts and transmission coefficients for an independent random sample, Indianapolis, IN, 1980.*

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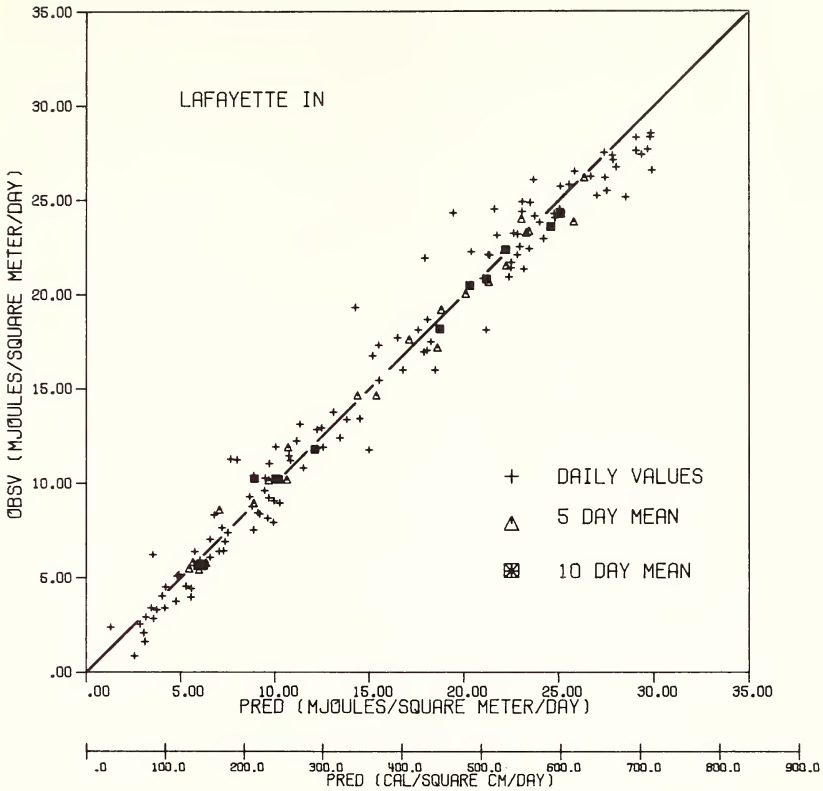

FIGURE 6. *Scatter diagram of measured daily solar radiation on that predicted with hourly cloud amount and transmission coefficients for an independent random sample, West Lafayette, IN, 1976.*

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Nitrogen Contents and Ammonium Fixing Capacities of Soil Separates

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Introduction

Nelson *et al.* (1977) have recently found significant positive correlations between the clay content and the levels of organic C, total N, total P, total S, and fixed ammonium N and ammonium fixing capacities of 48 Indiana surface soils. These data suggested that organic matter, fixed ammonium, and ammonium fixing capacities of soils were primarily associated with the clay fraction. However, little information is available on the relative amounts of organic C, total N, and fixed ammonium or ammonium fixing capacities of soil separates. Nommik (1965) in reviewing data from several studies reported that the ammonium fixing capacities of soils tend to increase with increasing clay content, but some studies suggested that the sand and silt fractions also fix added ammonium N. A few studies have shown that the clay fraction has higher contents of fixed ammonium and potassium than silt or sand fractions (Hinman, 1964; McLean and Brydon, 1963), however, Genrich (1972) found that the silt fraction of Iowa soils contained much higher levels of fixed potassium than the clay fraction. The clay fraction of Iowa soils has been shown to contain most of the organic C, total N, and total S (Genrich, 1972).

The lack of definitive information on the distribution of organic matter, fixed ammonium, and ammonium fixing capacities in soil separates prompted this investigation. The objective of the work was to determine the relative amounts of organic C, total N, exchangeable ammonium, fixed ammonium, and ammonium fixing capacity present in sand, silt, and clay fractions of diverse agricultural soils.

Materials and Methods

The soils selected for the study (Table 1) represented a wide range in texture, organic matter content, clay mineralogy, and fixed ammonium N concentration. The soils were collected from throughout North America: Clarence and Marshall from Iowa; Yolo from California, Nicollet from Minnesota, and Whatcom from British Columbia. The Clarence and Yolo samples were subsoils, whereas the other samples were surface soils. The clay fraction of Marshall, Nicollet, and Yolo soils was composed largely of montmorillonite with lesser amounts of illite and kaolinite. The principal clay mineral in Clarence soil was illite, although significant amounts

TABLE 1. *Characteristics of soils used in the study.*

Soil[+]	Depth	Clay	Silt	Sand	Organic C	Total N	Fixed NH_4^+-N	pH
	cm	% by weight				μg/g		
Clarence sic	38-58	43	44	14	0.87	920	217	6.0
Yolo cl	38-58	33	47	21	0.79	810	273	7.6
Marshall sicl	0-15	33	65	2	2.20	2090	268	4.8
Nicollet l	0-15	24	37	39	1.56	1340	85	6.9
Whatcom sil	0-15	11	75	14	1.27	810	96	6.4

[+] sic, silty clay; cl, clay loam; sicl, silty clay loam; l, loam; sil, silt loam.

of montmorillonite, vermiculite, and kaolinite were present. Chloritized vermiculite was the predominate clay mineral in the Whatcom soil.

Soil sample (< 2-mm) were separated into sand, silt, and clay fractions by an ultrasonic dispersion and seiving-sedimentation technique (Genrich and Bremner, 1974) designed to preclude alteration of the chemical composition of fractions during separation. To verify the efficacy of the separation procedure, the mechanical composition of soils was also determined by the pipette method following dispersion of solids with sodium metaphosphate and hydrogen peroxide (Kilmer and Alexander, 1949). Organic C, total N, fixed ammonium N, and exchangeable ammonium N in whole soils and soil separates were determined by procedures of Mebius (1960), Bremner (1965), Silva and Bremner (1966), and Keeney and Bremner (1966), respectively. The pH of whole soils was measured by glass electrode in a 1:1 soil:water mixture.

Ammonium fixing capacity was determined by three methods. In all methods the whole soils or separates (0.5 g) were amended with 1 ml of 1*N* NH_4Cl, incubated or dried, and analyzed for fixed ammonium N by the procedure of Silva and Bremner (1966). The difference in fixed ammonium N before and after amendment of the sample with 1*N* NH_4Cl was defined as ammonium N fixing capacity. After soils or soil separates were amended with 1*N* NH_4Cl a portion of the samples were allowed to stand at 25°C for 24 hours (moist ammonium N fixing capacity), a portion of the samples were dried in a dessicator at 25°C (air-dry ammonium N fixing capacity), and the remainder of the samples were dried at 105°C (oven-dry ammonium N fixing capacity).

All concentration data are expressed on a moisture-free basis and represent averages for three replicate determinations. Data presented in Tables 2 and 4 represent average values for the 5 soils. Data for all soils followed the trends exhibited by the average values for the 5 soils. Linear correlation analyses were performed by procedures outlined by Steele and Torrie (1960).

Results and Discussion

On the average the concentrations of organic C, total N, exchangeable ammonium N, and fixed ammonium N in the clay fraction were higher than those in the whole soils or silt and sand fractions (Table 2). Likewise, the ammonium N fixing capacities of soils and separates followed the order: clay > whole soil > silt > sand. The concentrations of organic C, total N, and exchangeable ammonium N in the clay fraction were two and three times the levels in the whole soils and the silt fractions, respectively. However, the fixed ammonium N and moist and air-dry ammonium N fixing capacities were only about 1.5 times higher in the clay fraction than in the whole soil. Oven-drying NH_4Cl-treated samples markedly increased the

TABLE 2. *Average organic C, total N, and fixed ammonium concentrations and ammonium fixing capacities of whole soils and soil separates.*

Soil component	Organic C	Total N	Organic C/N	Exch. NH_4^+–N	Fixed NH_4^+–N	Ammonium fixing capacity		
						Moist	Air-dry	Oven-dry
	%			μg/g	μg N/g			
Whole	1.34	0.119	13.6	15	188	97	185	201
Clay	2.92	0.278	12.0	28	311	127	276	414
Silt	0.98	0.066	18.8	8	130	47	69	87
Sand	0.66	0.021	44.6	2	60	17	33	33

ammonium N fixing capacity of the clay fraction as compared to the increases obtained from oven-drying whole soils.

The organic C/organic N ratio in whole soils and soil separates followed the order: clay < whole soil < silt < sand (Table 2). This finding suggests that organic matter associated with the clay fraction was well humified (low C/N) whereas organic matter in the sand fraction was largely undecomposed residues (high C/N). Air-drying markedly increased the ammonium N fixing capacity of soils and soil separates, but oven-drying had little effect above that of air-drying in all sample expect the clay fractions. This finding suggests that the mechanism for ammonium fixation in clay differs from that of the other soil separates.

It is significant that the silt fraction of soils contained relatively high concentrations of organic C, total N, and fixed ammonium N and had substantial ammonium N fixing capacity because silt is the predominate separate in many Indiana soils. The sand fraction of soils contained higher levels of organic matter and fixed ammonium N than would be expected because many soil scientists consider sand to be essentially inert. It was especially surprising to find that sand had a modest ammonium N fixing capacity.

Calculations were made to determine if the method used to obtain the soil separates altered the chemical composition of fractions. The organic C, total N, and fixed ammonium N concentrations of Nicollet and Whatcom soils were determined by chemical analysis and estimated by summing the amounts present in the three size fractions (Table 3). In all cases the values obtained by summation agreed with

TABLE 3. *Comparison of organic C, total N, and fixed ammonium N concentrations determined directly on whole soils and calculated from analysis of soil separates.*

Soil	Method of estimation	Organic C	Total N	Fixed NH_4^+ – N
		% by weight		μg/g
Nicollet 1	Direct	1.56	0.134	85
	Sum of separates	1.46	0.133	95
Whatcom sil	Direct	1.27	0.081	96
	Sum of separates	1.29	0.083	87

those from direct analysis. This finding indicates that the method used to fractionate soils did not alter the characteristics of soil separates.

Although the clay fraction represented an average of only 29% of the soil mass, 58% of the organic C, 65% of the total N, and 52% of the fixed ammonium N in soil was present in this fraction (Table 4). In addition, the clay fraction was

TABLE 4. *Percentage of the total amounts of organic C, total N, fixed ammonium N, and ammonium-fixing capacities of soils present in soil separates.*

Soil component	Mechanical composition	Organic C	Total N	Fixed NH_4^+ – N	NH_4^+ – N fixing capacity		
					Moist	Air-dry	Oven-dry
	% of total amount						
Clay	29	58	65	53	53	62	67
Silt	53	40	34	42	43	33	30
Sand	18	3	2	5	4	5	4

responsible for 53 to 67% of the ammonium N fixing capacity of soils. The silt fraction representing 53% of total soil mass contained 40, 34, and 42% of the organic C, total N, and fixed ammonium N in soils, respectively. From 30 to 43% of the ammonium N fixing capacity of soils was associated with the silt fraction. The sand fraction (18% of soil mass) accounted for < 5% of the organic C, total N, and fixed ammonium N in soils and was responsible for < 5% of the ammonium N fixing capacity of soils. These findings point out the importance of the clay fraction as a 'storehouse' for nutrients, but also suggest that the silt fraction is of significance in regards to nutrient cycling in soils.

Linear correlation analyses were performed to determine statistical relationship between the amounts of soil separates (clay and silt) and the fixed ammonium N concentration and the ammonium N fixing capacities of soils (Table 5). The fixed ammonium N levels were correlated with the % clay in soils, but were not correlated with % silt. However, a higher correlation coefficient was obtained between fixed ammonium N and the sum of % clay and a fraction (.33 to .5) of % silt than between fixed ammonium N and % clay. This finding suggests that the silt fraction is important in contributing to the fixed ammonium N level in soils, but the significance of the silt fraction is much less than that of the clay fraction. The moist and air-dry fixing capacities of soils were correlated with the % clay, but not with % silt. Combining % clay with some portion of % silt did not result in improved correlations. This finding suggests that silt plays a small role in influencing the magnitude of ammonium N fixation in soils although the silt fraction does contribute to the fixation capacity.

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TABLE 5. *Relationships between the proportion of soil separates and the fixed ammonium N concentrations and ammonium fixing capacities of soils.*

Independent variable	Dependent variable	Correlation[+] coeff. (r^2)
% clay	Native fixed NH_4^+ – N, μg/g	+ .54*
% silt	Native fixed NH_4^+ – N, μg/g	+ .00
% clay + 0.5 (% silt)	Native fixed NH_4^+ – N, μg/g	+ .73 **
% clay + .33 (% silt)	Native fixed NH_4^+ – N, μg/g	+ .74**
% clay	Moist NH_4^+ – N fixing cap., μg/g	+ .63*
% silt	Moist NH_4^+ – N fixing cap., μg/g	+ .50
% clay + 0.5 (% silt)	Moist NH_4^+ – N fixing cap., μg/g	+ .14
% clay + 0.33 (% silt)	Moist NH_4^+ – N fixing cap., μg/g	+ .32
% clay	Air-dry NH_4^+ – N fixing cap., μg/g	+ .71 *
% silt	Air-dry NH_4^+ – N fixing cap., μg/g	+ .38
% clay + 0.5 (% silt)	Air-dry NH_4^+ – N fixing cap., μg/g	+ .26
% clay + 0.33 (% silt)	Air-dry NH_4^+ – N fixing cap., μg/g	+ .46

[+] *, significant at the 95% confidence level; **, significant at the 99% confidence level.

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The New Decade and Changing Normals of Temperature and Precipitation in Indiana

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Introduction

"Normals" of temperature and precipitation, as well as their estimates, are ever changing to the disappointment of many who presume them to be climatological bench marks in meteorology. Reference to departures from normal regularly used by the news media, the heating and cooling industry, and by agriculturalists assume a semi-permanent fixed average, called the normal. Most countries adhere to the World Meteorological Organization definition of a temperature or precipitation normal as a 30-year average ending with the last complete decade. Continous constant quality exposure of instruments at one location is required to prepare station normals. For climatological division or district normals, it is also assumed that the network or location of stations within the division, has not changed significantly. Temperature and precipitation normals are calculated at the end of each decade for the preceeding 30-years and used as normals for the next ten years. What happens when the records of the 1970s replace those of the 1940s? The answer is the subject of this paper.

Data and Procedures

The easiest way to appraise the new normals is to consolidate the 1951-80 station averages into a revised area or division normal. A preliminary listing of the new station normals calculated by the National Climatic Center were used. Indiana is divided into nine climatic divisions as outlined in Figure 1. These division boundaries have been used in *Climatological Data, Indiana* (U.S.D.C., 1956-80) and other climatological publications since October 1956. They are also the same as the Crop Reporting Districts used by the U.S. Department of Agriculture in summarizing crop and livestock statistics.

Results and Discussion

Precipitation

Normals of total annual precipitation, average of 1951-1980, have undergone very little change from those of 1941-70, used in the 1970s, and even from those of 1931-60. The new normals to be used in the 1980s are given in Table 1. There are distribution changes within the year, however. In January in the southwest division precipitation totals decreased from 3.90 inches in 1931-60, to 3.28 in 1941-70, and 2.87 for the new normals. This winter decrease is offset by an increase in July, from 3.56 in the 1931-60 period, 4.32 in the 1951-80 period. The change is less in the other divisions. If true, this has important agricultural significance in Indiana. The state usually has an excess of winter precipitation and almost always has less precipitation than required in the summer. The southwest division has the greatest evaporation and has the highest drought probabilities.

Temperatures

New average divisional daily temperature normals, shown in Table 2, range from 23.0°F. in January in northwest Indiana to 30.2°F. in the southwest. The range in July is much less, from 73.1°F. in north central to 77.4° in southwest. Daily

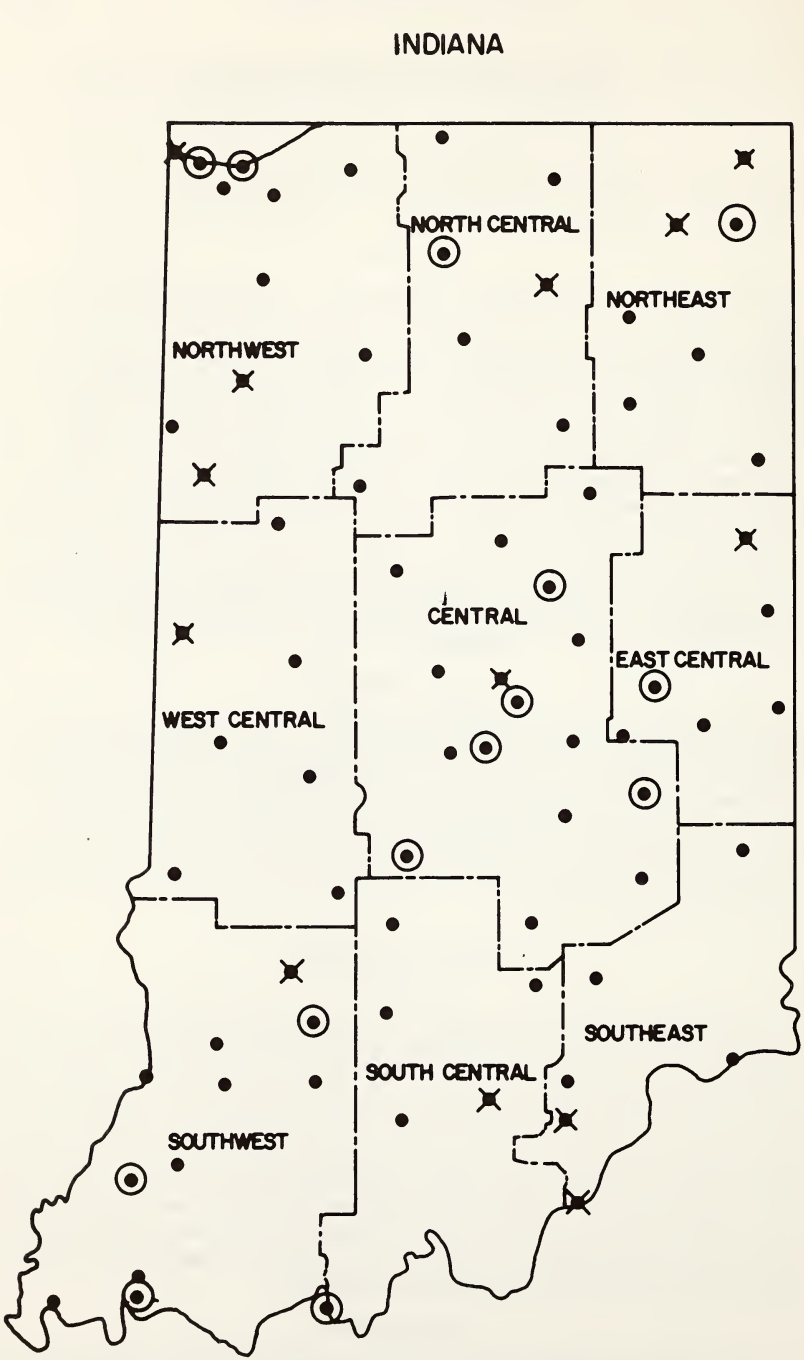

FIGURE 1. *Temperature stations included in calculation of division normals. Deletions (X) and additions (0) from 1931-1960 to 1951-1980 normals.*

TABLE I. *Average Monthly Precipitation, Indiana Divisions, 1951-1980.*

Division	Jan.	Feb.	Mar.	Apr	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Northwest	1.91	1.66	2.83	4.04	3.43	4.21	4.03	3.70	3.35	2.94	2.50	2.49	37.09
North Central	2.05	1.81	2.83	3.94	3.42	4.12	4.00	3,64	3.11	2.78	2.66	2.55	36.91
Northeast	2.10	1.84	2.97	3.65	3.55	3.77	3.68	3.26	2.84	2.52	2.72	2.53	35.43
West Central	2.36	2.12	3.37	3.92	4.09	4.51	4.41	3.62	2.94	2.56	3.01	2.83	39.74
Central	2.49	2.27	3.29	3.90	4.01	4.07	4.41	3.52	2.82	2.56	3.01	2.85	39.20
East Central	2.48	2.12	3.23	3.97	3.93	4.25	3.95	3.44	2.75	2.52	2.96	2.77	38.37
Southwest	2.87	2.73	4.38	3.98	4.40	3.92	4.32	3.44	2.90	2.50	3.44	3.36	42.24
South Central	3.17	2.80	4.31	4.00	4.47	4.32	4.58	3.64	2.95	2.57	3.52	3.39	43.72
Southeast	3.24	2.90	4.22	3.86	4.25	4.07	4.40	3.43	3.03	2.64	3.25	3.14	42.43

TABLE 2. *Average Daily Temperature, Indiana Divisions, 1951-1980.*

Divisions	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Northwest	23.0	27.0	37.0	49.6	60.2	69.6	73.4	71.7	65.2	54.1	40.6	28.9	50.0
North Central	23.4	26.9	36.8	49.6	60.1	69.6	73.1	71.1	64.6	53.1	40.4	29.2	49.7
Northeast	24.0	27.1	37.2	49.8	60.2	69.8	73.3	71.4	64.8	53.3	40.5	29.4	50.1
West Central	25.5	29.4	39.4	52.2	62.3	71.4	75.0	73.1	66.6	54.9	42.0	31.1	51.9
Central	25.6	28.9	38.9	51.4	61.6	70.6	74.1	72.2	65.9	54.0	41.5	30.9	51.3
East Central	24.7	27.7	37.8	49.9	60.2	69.4	73.0	71.2	64.5	52.6	40.6	30.1	50.1
Southwest	30.2	34.1	43.7	56.1	65.2	73.9	77.4	75.7	69.3	57.4	45.0	35.1	55.3
South Central	29.2	32.6	42.0	54.2	63.4	72.0	75.6	74.1	67.6	55.5	43.8	34.0	53.7
Southeast	29.4	32.7	42.2	54.1	63.5	72.1	75.8	74.2	67.8	55.6	43.8	34.3	53.8

mean temperatures are the averages of the daily maximum temperatures of Table 3, and daily minimum temperatures of Table 4.

A comparison of the new temperatures normals with those used the past ten years shows some very interesting changes. In Figure 2, the divisional temperature normals for 1951-80 and 1931-60 are shown as departures from the 1941-70 normals. For Central Indiana the departures are also shown for the 1931-50 normals. For practically all months and divisions lower temperatures are indicated by the 1951-80 normals. Those for January and February are the most drastic. No doubt the severe winters of 1977, 1978 and 1979 contributed greatly to reducing the average. The second dominant feature in Figure 2 is the minimal change during November and December in the western and northern divisions.

Sources of "Non-climatic" Trend

The configuration of climatological stations used to compute a divisional average changes from one decade to another. This introduces bias into the estimates of the "normal" climate. One source of bias concerns the rule that a station must operate continuously for 30 years or more. Otherwise, it is dropped from the group being used for determining the divisional average. On the other hand, stations newly attaining a record length of three decades enter the averaging process. With a north to south temperature and precipitation gradient existing there may be some increase in temperature and precipitation shown by the divisional average if there is a relative increase in stations in the southern part of the division. The opposite is true if there are relative additions of stations in the north. Changes in network configuration of stations used for the normals in 1951-80 from that in 1931-60 are shown in Figure 1.

Another bias that climatologists, working with once daily observations of

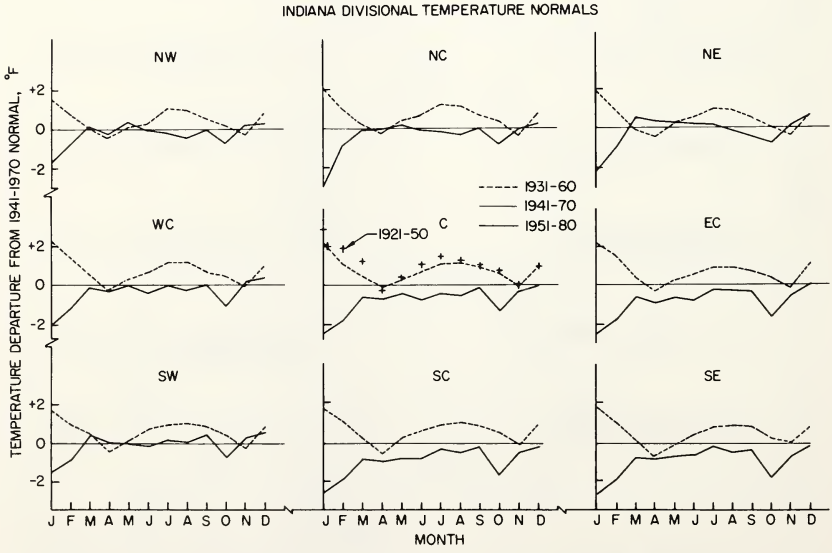

FIGURE 2. *New normals of temperature (____) shown as departures from base line 1941-1970, departures for 1931-1960 (----), and for central Indiana, 1921-1950 (+ + +).*

TABLE 3. *Average Daily Maximum Temperature, Indiana Divisions, 1951-1980.*

Divisions	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Northwest	31.2	35.6	46.0	60.4	71.9	81.3	84.5	82.8	76.9	65.3	49.3	36.5	60.1
North Central	31.6	35.8	46.2	60.9	72.1	81.5	84.7	82.8	76.9	64.9	49.3	36.9	60.3
Northeast	31.9	35.8	46.5	61.0	72.0	81.6	84.7	83.1	77.0	65.0	49.0	36.8	60.4
West Central	34.4	39.0	49.4	63.4	74.0	83.0	86.5	84.8	79.2	67.4	51.7	39.5	62.7
Central	34.3	38.3	48.7	62.6	73.1	82.0	85.4	83.8	78.3	66.4	51.1	39.2	61.9
East Central	33.7	37.2	47.7	61.3	72.0	81.1	84.7	83.3	77.2	65.2	50.2	38.5	61.0
Southwest	39.0	43.7	53.9	67.5	76.9	85.5	88.6	87.2	81.5	70.1	55.0	43.6	66.0
South Central	39.0	43.2	53.1	66.5	76.0	83.9	87.4	86.5	80.8	69.4	54.9	43.5	65.4
Southeast	38.8	43.1	53.3	66.4	76.0	84.0	87.4	86.3	80.7	69.0	54.5	43.4	65.2

TABLE 4. *Average Daily Minimum Temperature, Indiana Divisions, 1951-1980.*

Divisions	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Northwest	14.7	18.4	27.9	38.7	48.4	57.9	62.3	60.5	53.5	42.8	31.9	21.3	39.9
North Central	12.6	18.0	27.4	38.2	48.1	57.6	61.4	59.4	52.2	41.2	31.5	21.5	29.1
Northeast	16.1	18.4	27.8	38.6	48.4	57.9	61.8	59.7	52.6	41.6	32.0	22.0	39.7
West Central	16.6	19.8	29.4	40.9	50.5	59.7	63.4	61.3	54.0	42.3	32.2	22.6	41.1
Central	16.8	19.5	29.0	40.2	50.0	59.2	62.8	60.5	53.4	41.6	31.9	22.6	40.6
East Central	15.7	18.2	27.8	38.4	48.4	57.6	61.2	59.0	51.8	40.0	30.9	21.7	39.2
Southwest	21.3	24.4	33.4	44.6	53.4	62.3	66.2	64.1	57.0	44.7	35.0	26.6	44.4
South Central	19.4	21.9	30.8	41.9	50.8	60.0	63.8	61.6	54.4	41.65	32.6	24.5	41.9
Southeast	20.0	22.3	31.1	41.8	51.0	60.2	64.1	62.1	54.8	42.2	33.0	25.0	42.3

maximum and minimum temperatures, relate to the change of observation time from evening hours to morning hours. Operational demands have tended to favor this shift of time in reading the instruments. It was shown by Schaal and Dale (1977) that this shift induces a lower mean minimum and mean temperature in computing the 24-hour (observational day) average temperature. The divisional temperature is in turn reduced, other factors remaining the same. For example, the lowest temperature in a 24-hour period is reported twice when the temperature at the beginning is much lower than at the end of the 24 hours which is often the case for a 7 a.m. observation time. If the observation time is 6 p.m. there is no carry-over minimum temperature, but there may be a carry-over maximum and an upward temperature bias. The obvious trend in Figure 3 contributes "non-climatic cooling" to the normals.

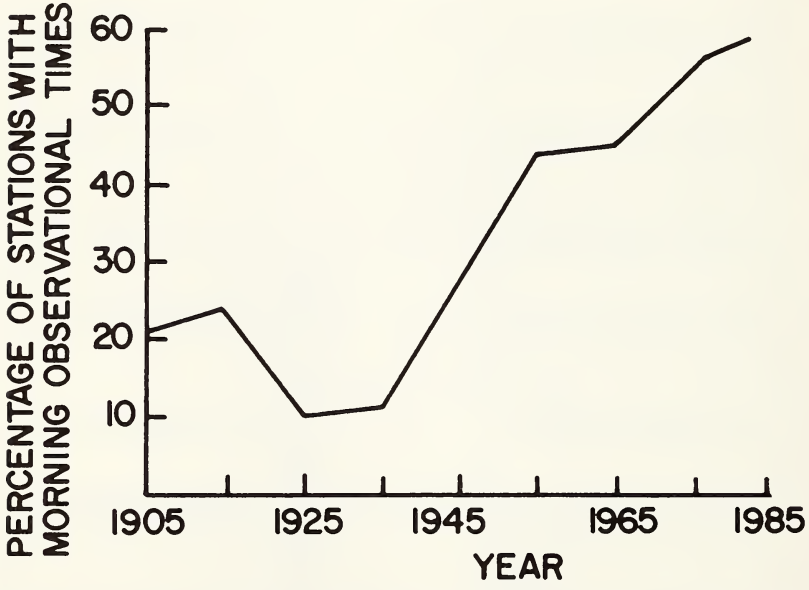

FIGURE 3. *Percentage of stations published with temperatures obtained with morning observational times. Climatological Data, Indiana, for indicated year.*

An endeavor to evaluate these temperatures biases caused by changes in observation times, instrumentation and network configuration was described by Nelson et al. (1979). Briefly, monthly divisional and temperature averages for summer months were adjusted using stations with consistently the same departures from the area mean temperature to adjust temperatures of other stations showing sharp changes from the division average within a few months. The divisional averages in *Climatological Data*-Indiana were then adjusted to the 1976 network configuration, and the average for the state was computed using area weighted division averages, National Climatic Center (1978). In Figure 4 from Nelson et al. (1979), August normals for 1931-60, 1941-70, and 1951-80 were plotted. They correspond closely to the corrected year-to-year August regression. The new temperature normals, at least for the state, seem to agree with the state adjusted

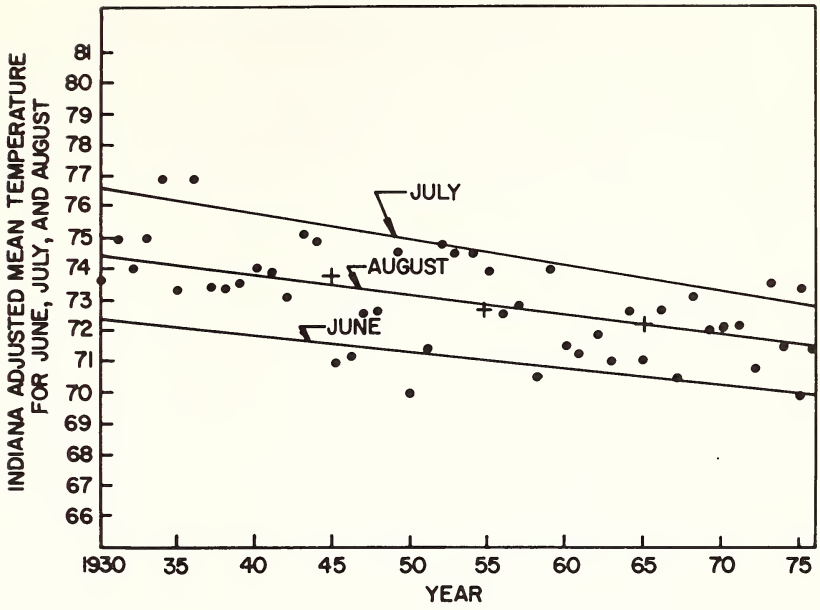

Figure 4. *Indiana state average mean temperatures for June, July and August, 1930-76, calculated for a 1976 base, (Nelson et al. 1979). Lines represent separate regressions of indicated monthly mean temperature on year. State average mean temperature normals for August for 1931-1960, 1941-1970, and 1951-1980 plotted at middle of indicated 30-year period.*

mean temperature series for August, showing a climatic cooling tend of about 2°F. for the last 30 years.

It is believed that the spatial variability of precipitation is so great that changes in network configuration are less important and the new normals are accepted as the best estimates available.

Conclusion

The use of the new temperature normals in the 1980s will likely result in an increase of above normal temperatures because the normal has been lowered from the previous one. The converse also is likely true: In recent years normals have been too high resulting in a bias toward reporting more below normal temperatures than warranted. Most impact will be felt in the more objectively-used heating degree day normals. Their greater accumulation through a season will raise the level of normalcy and result in more below normal heating degree day seasons than in recent past seasons.

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Soil Test Levels in Indiana in Relation to Plants to be Grown

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Introduction

Soil test summaries made by the Purdue University Soil Testing Laboratory and reported by Barber and Bronson (1,2) for 1952-1954, included average fertilizer rates of P_2O_5, and K_2O for corn by county and by soil group or region. In their soil test frequency distribution for 1962, Hood and Stivers (5) included N fertilizer recommendations for wheat (*Triticum aestivum* L.), and oats (*Avena sativa* L.) as well as for corn (*Zea mays* L.). In his 1970 soil test summary Hood (4) included soil sample data intended for use in growing corn, soybeans (*Glycine max* L.), forage crops, and hay or pasture in selected Indiana counties. In their 1972-1974 soil test summary, Hood and Stivers (6) separated samples for growing corn and/or soybeans from forage crops.

The specific purpose of this report is to determine from a group of selected crops, those having the highest percentages in either very high levels or in very low soil test levels of pH, available P, and available K.

Materials and Methods

The data used in this report are products of the public services of the Purdue University Plant and Soil Analysis Laboratory. Laboratory chemical procedures used were reported by McLean (8) for soil pH, by Knudsen (7) for Bray-1 P, and by Carson (3) for soluble and exchangeable K.

Crops to be grown following soil testing were the first ones listed on the information sheet accompanying the soil samples.

Statistical summaries of the soil test data by level of the test, by county, and by crop were prepared using a computer program written by Philip J. Hess. Five levels of soil pH, five levels of available P, and five levels of available and water soluble K were used.

The eight crops or plantings compared in this report were chosen because of the large numbers of samples of corn and soybeans or because of the large variation from the mean of the six remaining crops—turf, vegetable gardens, grass-legume seedings, grass-legume maintenance, ornamental plantings, and tobacco.

The three sampling period used for this study were April 17, 1979 through July 2, 1979; July 3, 1979 through July 1, 1980; and April 1, 1981 through June 26, 1981. There were 2,995 soil samples tested in the first period, 13,168 were tested in the second period, and 3,022 were tested in the third period.

Large variations among the three sampling periods with respect to percentages of samples found in the highest level of soil pH, the highest level of available P, and the highest level of available and water soluble K for areas intended to grow soybeans and/or tobacco were found. In addition, there were large variations among the three samplings periods in percentages of samples in the lowest level of P which were intended to maintain grasses and legumes. Therefore, the data for the three sampling periods were not combined so that these variations could be seen.

The summary for the 25 crops or plantings included, in addition to those listed above, the following crops or groups with the total number of samples tested for each as follows: miscellaneous, 481; wheat, 404; legume maintenance, 278; no recommendation requested, 263; grass maintenance, 218; oats, 113; grass seeding, 88; roses, 40; corn silage, 24; popcorn, 22; tomatoes (*Lycopersicon esclentum* L.) 22; wheat-soybeans double crop, 12; grain sorghum (*Sorghum biclor* L.), 10; sudan grass (*Sorghum sudanense* P.), 10; rye (*Secale cereale*), 5; barley (*Hordeum vulgare* L.), 4.

Results and Discussion

Numbers of soil samples tested for the eight crops or plantings compared in this study are given in Table 1. The 7,178 soil samples tested for corn was greater in number than those of any other crop or planting. The 17,091 samples tested for these eight crops were 89.1% of the 19,185 samples tested for all 25 crops.

TABLE 1. *Crop or planting to be grown and numbers of samples tested in three sampling periods of 1979-1981*

Crop or planting	No. of samples	Percent of all samples	Crop or planting	No. of samples	Percent of all samples
Corn	7,178	37.4	Grass-legume maintenance	1,054	5.5
Soybeans	2,607	13.6	Ornamental plantings	276	1.4
Turf	2,168	11.3	Tobacco	143	0.8
Vegetable garden	1,859	9.7	All others	2,094	10.9
Grass-legume seedings	1,806	9.4	All 25 crops or plantings	19,185	100.0

Differences in soil pH in relation to crops to be grown are given in Table 2. In all sampling periods percentages of soil samples with a pH of 6.6 or higher were greater for turf, vegetable gardens, and ornamental plantings than for corn, soybeans, tobacco, grass-legume seedings, or grass-legume maintenance crops. Information given on turf, garden, and landscape information sheets indicated that many producers, particularly of vegetable gardens, applied limestone without having test information indicating that the limestone was needed. Also, lawns, golf greens, and ornamental plantings are often sprinkler irrigated with hard water which makes the soil more alkaline.

Percentages of soil samples at the lowest end of the soil pH range, 0-4.7, were very small. They were greatest for tobacco (2.4%) and for ornamental plantings

TABLE 2. *Percent of samples having a soil pH of 6.6 or higher classified by crop to be grown and sampling period*

Crop or planting	4/17/1979 to 7/2/1979	7/3/1979 to 7/1/1980	4/1/1981 to 6/26/1981
	%		
Corn	26.6	41.8	29.4
Soybeans	22.7	42.3	33.6
Turf	79.4	78.6	75.5
Vegetable gardens	74.2	75.8	73.9
Grass-legume seedings	39.0	44.2	34.0
Grass-legume maintenance	49.1	57.1	39.3
Ornamental plantings	67.5	79.6	76.0
Tobacco	52.9	29.4	31.7
All 25 Crops or plantings	38.2	50.3	44.8

(2.0%) in the last sampling periods. For all other crops percentages were lower than 2.0 in all sampling periods. Corn which was in this group, was more uniform that other crops, that is in percentages among the three sampling periods.

Crops having a high percentage of soil P tests > 70 pp2m of P (considered very high) included tobacco and vegetable gardens (Table 3). Turf and ornamental plantings were higher than the average of all 25 crops but lower than tobacco and vegetable gardens. Information sheets received in the laboratory with the soil samples indicated that application of chemical fertilizers generally had been generous. Tobacco and vegetable gardens are frequently heavily fertilized because they are high value crops. Generous amounts of chemical fertilizer also had been applied to turf and ornamental plantings, apparently to improve growth and appearance.

TABLE 3. *Percent of samples having a phosphorus test greater than 70 pp2m of P classified by crop to be grown and sampling period*

Crop or planting	4/17/1979 to 7/2/1979	7/3/1979 to 7/1/1980	4/1/1981 to 6/26/1981
	%		
Corn	44.5	35.2	35.3
Soybeans	34.3	29.8	26.9
Turf	50.2	53.5	44.2
Vegetable gardens	73.8	70.9	66.3
Grass-legume seedings	23.9	13.6	23.1
Grass-legume maintenance	24.2	12.0	15.4
Ornamental plantings	60.0	52.7	56.0
Tobacco	64.7	61.2	80.5
All 25 Crops or plantings	41.0	37.6	39.8

Crops having the most soil samples with very low P tests, (0-10 pp2m of available P) were grass-legume seedings and grass-legume maintenance (Table 4). Grass-legume maintenance samples had 29.9 to 47.8% in the very low P level, while 25.9 to 37.4% of soil samples for grass-legume seedings were in this very low P level. For the other six crops listed in Table 1, the highest percentage of samples in this very low level was 13.4, and the lowest was 2.4. Some probable reasons for these low P tests for grass-legume seedings and for grass-legume maintenance have been given in the information sheets accompanying the soil samples. They

TABLE 4. *Percent of samples having a phosphorus test of 0-10 pp2m of P classified by crop to be grown and sampling period*

Crop or planting	4/17/1979 to 7/2/1979	7/3/1979 to 7/1/1980	4/1/1981 to 6/26/1981
	%		
Corn	5.0	8.0	10.2
Soybeans	3.1	5.8	4.8
Turf	12.3	7.2	5.1
Vegetable gardens	3.6	5.3	3.6
Grass-legume seedings	33.9	37.4	25.9
Grass-legume maintenance	47.8	41.2	29.9
Ornamental plantings	12.5	13.4	4.0
Tobacco	11.8	2.4	2.4
All 25 Crops or plantings	13.5	12.6	9.8

were (1) prior to these soil tests this land had been in pasture where little commercial fertilizer or limestone had been applied or, (2) the land had been recently cleared from woods, or (3) the land had not been farmed for many years prior to making the grass-legume seeding.

Crops having the highest percentages of soil samples with K tests greater than 300 pp2m (classed as very high) in K were vegetable gardens and tobacco (Table 5). Ornamental plantings were not as high as expected, although the trend seemed to be higher in each succeding sampling period.

TABLE 5. *Percent of samples having a potassium test greater than 300 pp2m of K classified by crop to be grown and sampling period*

Crop or planting	4/17/1979 to 7/2/1979	7/3/1979 to 7/1/1980	4/1/1981 to 6/26/1981
	----------	%	----------
Corn	28.4	20.8	21.3
Soybeans	28.1	11.0	14.1
Turf	20.9	24.5	16.4
Vegetable gardens	50.8	51.4	54.9
Grass-legume seedings	14.0	13.5	15.6
Grass-legume maintenance	18.0	15.2	22.2
Ornamental plantings	25.0	33.3	34.0
Tobacco	41.2	35.3	56.1
All 25 Crops or plantings	26.3	22.2	25.1

Grass-legume seedings and grass-legume maintenance crops also had the highest percentages of soil samples with very low K tests, that is 0-80 pp2m of available K, in two of the three sampling periods. Percentages in this level of K were 8.6 to 9.9% for grass-legume seedings and 8.8 to 10.6% for grass-legume maintenance. These percentage values were relatively very small in comparison to the percentages in the very low P level for the same two crops. In the April 1, 1981, through June 26, 1981, sampling period, turf was highest with 6.3% in the 0-80 pp2m of K level.

When the soil samples from all 25 crops or plantings were considered, the percentages of samples in the highest levels of soil pH, available P, and available K were 47.5, 38.5 and 23.3 respectively.

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Fertilization Fails to Increase Diameter Growth of Selectively Managed Northern Hardwoods

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Introduction

High costs of land ownership, increasing stumpage prices, and short supplies of the better grades of veneer and sawlogs have stimulated interest in fertilizing high-quality northern hardwood crop trees. The value of these species justifies management on an individual tree basis. Previous fertilization studies in Lake States northern hardwoods have been conducted in unmanaged even-age, pole-size stands (8, 9, 10). Results of fertilizing individual sawlog-size northern hardwoods in a selectively managed all-age stand are reported here.

Stand and Site Conditions

This study was conducted in a 16.2 ha (40-acre) all-age northern hardwood stand near Amasa, in western Upper Michigan. The stand is managed for continuous production of high-quality veneer and sawlogs by single tree selection on a 12-year cutting cycle. The site is on a nearly level plain of glacial till with a 0-2% westerly slope. Soils are of the Stambough-Goodman complex, a moderately well-drained Alfic Haplorthod (coarse, loamy, mixed, frigid) developed from a 76-152 cm (30-60 in.) silt cap over gravelly, loamy sands, Internal drainage is impeded somewhat by the textual discontinuity of the underlying material and an accumulation of clay materials (B_t horizon) in the lower profile. The textural discontinuity and the argillic horizon result in a temporary perched water table.

Site index (age 50) for sugar maple on these soils is about 21m (65 feet). In the original stand, more than 60% of the trees 51cm (20 in.) dbh and greater had merchantable heights of 2½ to 3½ 5-m (16-ft.) logs, also indicating a good site. Stand and site conditions were unusually uniform over the study area with surface soil pH 5.5, 5.0% organic matter, and 0.25% total N; available nutrients (kg/ha) were: 28 P, 165 K, 1,000 Ca, and 100 Mg (25, 147, 895 and 90 lbs/acre).

Initial timber volume on the 40 acres was 393 Mbf with 10% cull. Over 80% of the volume was sugar maple; the balance consisted of 9.2% yellow birch (*Betula alleghaniensis* Britton), 7.9% American basswood (*Tilia americana* L.), and 2.5% American elm (*Ulmus americana* L.). Basal area averaged 21 m^2/ha (91 ft. ^{2}/acre) in trees 25 cm (10 in.) dbh and larger; total basal area was 32 m^2/ha (140 $ft.^2$/acre). Diameters ranged up to 76 cm (30 in.) dbh and merchantable heights to 3½ 5-m (16 ft.) logs. The initial cut in 1936 removed 10.6 m^2/ha (46 $ft.^2$/acre) of sawlog basal area and 66% of the net volume.

An improvement cut in 1964 left a residual basal area of 11.5 m^2/ha (50 $ft.^2$/acre) in trees 25 cm (10 in.) dbh and larger; total basal area averaged 18m^2/ha (78 $ft.^2$/acre). Thus, when the stand as treated in 1970, midway through the cutting cycle, residual stocking was near optimum for stand development and growth of high-value logs (1). The improvement cut reduced cull volume to 1.2%. Net volume was 6.3 Mbf/acre: 88% maple, 7% yellow birch, 3% elm and 2% basswood. Volume

TABLE 1. *Species distribution of selected crop trees (number).*

Treatment	American Basswood	Yellow Birch	American Elm	Sugar Maple	Total[1]
Control	9	12	12	472	505
Fertilized	8	9	15	468	500
Total	17	21	27	940	1,005

[1]Living trees at conclusion of study.

distribution between small 25-37 cm (10-14 in.), medium 38-49 cm (15-19 in.), and large 50-65 cm (20-25 in.) sawlogs was 21, 54, and 26% respectively.

Methods

The stand was divided into five 3.24 ha (8-acre) blocks; each was split into two plots. On each plot, approximately 100 (93 to 110) vigorous crop trees 25 to 65 cm (10 to 25 in.) dbh were selected, measured, and numbered. All sample trees were dominant or strong codominants with well-developed crowns; each contained at least one potential grade #1 5-m (16-ft.) sawlog. Crop trees on randomly selected plots were treated with 2.61 kg (5.75 lbs.) per tree of 20-20-20- N-P-K fertilizer, approximately 700 kg/ha N, 300 P, and 600 K. Fertilizer was surface broadcast over an approximately 1.0 m (3.3 ft.) wide band around the base of treated trees on 10 June 1970. A total of 502 trees were fertilized; there were 506 controls (Table 1). Diameter at breast height (dbh) of crop trees was measured in the fall after three and after six growing seasons following fertilization. Differences in dbh growth of sample trees on the five pairs of plots were evaluated by paired t-tests at the 0.05 probability level.

Forty core samples of the surface 30 cm (12 in.) of soil on each plot were composited, air-dried, and passed through a 2 mm sieve. Sub-samples of each composite sample were analyzed for N, P, K, Ca, Mg, pH, and organic matter content. Total N was determined by Kjeldahl analysis (2); Bray P_1 extractable P was measured colorimetrically. Exchangeable K, Ca, and Mg were determined by atomic absorption after extraction with neutral normal NH_4OAc, organic matter by loss-on-ignition, and pH with a glass electrode in a 1:1 soil-water suspension.

Results and Discussion

Species distribution on control and fertilized areas was nearly identical; the number of maples differed by only four trees and the minor species by three or less (Table 1). Three maples died over the 6-year period; two of them had been fertilized. Mean annual diameter growth of minor species was slightly greater than that of maple, but there were not enough for valid comparisons and their presence did not change the overall mean (Table 2).

TABLE 2. *Mean annual diameter growth (cm) of sawlog-size northern hardwoods 6 years following fertilization (number of trees in parenthesis).*

Treatment	Sugar Maple	Other Species	All Species
Control	0.41	0.51	0.41
	(472)	(33)	(505)
Fertilized	0.41	0.48	0.41
	(468)	(32)	(500)

TABLE 3. *Periodic and total dbh growth (cm) of northern hardwood species by initial diameter.*

Initial dbh	1970-72		1973-75		6 Yr. Total	
	Control	Fertilized	Control	Fertilized	Control	Fertilized
25-37	1.14	1.17	1.19	1.24	2.34	2.39
38-49	1.17	1.17	1.30	1.35	2.46	2.54
50-65	1.17	1.19	1.32	1.32	2.51	2.51
All	1.17	1.17	1.27	1.30	2.44	2.49
Mean Annual Growth	0.38	0.38	0.43	0.43	0.41	0.41

Crop trees in all three diameter classes grew at essentially the same rate; medium and large sawlogs grew slightly more than smaller ones but the differences were minor (Table 3). Diameter growth of trees in all classes was slightly greater the second 3-year period than the first. Fertilization did not significantly increase dbh growth of crop trees in any of the three size classes during either measurement period, nor the 6-year total. Likewise, there were no significant differences in basal area growth. Six-year growth of crop trees averaged 1.65 m^2 (17.76 $ft.^2$) on control, and 1.63 m^2 (17.50 $ft.^2$) on fertilized plots. Mean annual growth per tree was 27.2 cm^2 (0.176 $ft.^2$) for control, and 27.1 cm^2 (0.175 $ft.^2$) for fertilized trees.

Mean annual dbh growth of both fertilized and control trees averaged 0.41 cm (0.16 in.), nearly 2.54 cm (1.0 in.) over the 6-year period. Diameter growth of dominant and codominant northern hardwoods in unmanaged stands on similar sites normally averages about 2.54 cm (1.0 in.) per decade. The greater growth observed in this study is typical of these species grown in selectively managed stands on good sites. Slightly greater growth of the minor species (Table 2) reflects the presence of basswood and elm, which generally grow somewhat faster than birch and maple.

The absence of a significant growth response following fertilization (Tables 2 and 3) was not unexpected. We have found similar results in pole-size stands of both birch and maple growing on comparable sites (8). The nearly equal growth of crop trees in each of the three diameter classes (Table 3) indicates that periodic cuttings will maintain superior growth of crop trees until they reach large sawlog sizes (3). Fertilization did not stimulate growth of one size class at the expense of another, as frequently occurs following fertilization of even-age stands (9). It can be inferred that there was no significant relation between treatment response and tree age because in managed stands, age and size are closely related (12). Tree vigor, as indicated by growth rate, did not influence treatment response; nearly

TABLE 4. *Number of trees that grew 2.5 cm or more in dbh during the 6 years following fertilization.*

Initial dbh	Treatment	
	Control	Fertilized
25-37	73	78
38-49	117	119
50-65	53	45
Total	243	242
Percent	48.1	48.4

half of the study trees grew 2.54 cm (1.0 in.) or more during the 6-year period, and fertilization did not change this proportion (Table 4).

The minor increase in growth of both control and fertilized trees during the second measurement period (Table 3) apparently was due to more available soil water. May through August precipitation averaged 35.4 cm (13.9 in.) during each of the first three growing seasons and 38.5 cm (15.2 in.) each of the second three.

Reasons for the lack of a fertilization response are not readily obvious. Site conditions determine: (a) the natural nutrient-element resources; (b) biological and chemical reactions that regulate nutrient availability; and (c) nutrient cycling processes (6). Available nutrients were similar to those of a previous study in which fertilization significantly increased foliar concentrations of applied nutrients but failed to stimulate radial growth of pole-size maple growing on a similar site (10). Although foliar analyses were not performed in the present study, adequate natural levels of soil nutrients and absence of a growth response (Table 3) suggest luxury consumption of added nutrients.

Nutrient uptake by competing vegetation was negligible since few seedlings or saplings were present adjacent to fertilized trees and nearby grasses and herbaceous vegetation were killed by the fertilizer treatment. The absorbing roots of forest-grown trees generally are concentrated within an area approximated by the crown periphery (4, 5), although individual maple roots may extend considerably further (11). The method of fertilizer application concentrated nutrients in a small portion of the rooting area. Death of grasses and herbaceous vegetation around fertilized trees suggest roolet mortality due to salt toxicity as a partial explanation for the absence of a growth response. In future studies, fertilizers should be applied over a larger area, more representative of the root distribution.

In the upper Lake States, northern hardwood species are the climax vegetation on the better forest sites, i.e. well-drained, medium and finer textured soils with high native nutrient levels. Rapid decomposition of logging slash (3), a thin litter layer, and favorable soil reaction (pH 5.5) indicate active nutrient cycling. Rapid growth and absence of a fertilization response (Table 3) indicate that nutrient availability is not a major factor limiting diameter growth. Previous studies in pole-size stands growing on similar sites have indicated that diameter growth was not limited by nutrient availability (8). Thus, efficient nutrient cycling and natural nutrient levels in the better northern hardwood soils appear adequate for rapid growth of these species in managed stands. The large sample size and uniform experiemental material (Table 1) lend credence to the results.

Management Implications

This stand is representative of large areas of managed northern hardwoods in the upper Lake States. Management by single tree selection results in a good proportion of large, high-value trees (13) and is the recommended silvicultural system for sustained yields of high-quality veneer and sawlogs (1). Stand density influences nutrient availability through root competition (7). Periodic cuttings maintain superior growth rates and are conducive to efficient nutrient cycling. Fertilization can be used in intensive forest management; the greatest responses have occurred with coniferous species growing on marginal or nutrient-deficient sites. However, fertilization is not likely to increase growth of managed northern hardwoods on medium and better sites.

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ZOOLOGY

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ABSTRACTS

The Krushinsky Apparatus: A Test for Self Awareness in Farm Animals. J. L. ALBRIGHT, Department of Animal Sciences, Purdue University, West Lafayette, Indiana 47907 and R. Kilgour and W. G. Whittlestone, Ruakura Animal Research Station, Private Bag, Hamilton, NZ.——The view that man is unique in the possession of language and that animals other than man have no mental experiences has been challenged by D. R. Griffin (The Question of Animal Awareness: Evolutionary Continuity of Mental Experiences. The Rockefeller University Press, New York, NY, 1976). Arguments persist and those interested in the welfare of farm animals are concerned by what animals would choose if presented the opportunity. One such early test to determine how animals think, anticipate, and react was developed by Krushinsky and his Russian colleagues (Krushinsky, L. V. 1965. Solution of Elementary Logical Problems by Animals on the Basis of Extrapolation. Progress in Brain Research Vol. 17. Cybernetics of the Nervous System. Edited by Norbert Weiner and J. P. Schade. Elsevier Publishing Co., New York, NY. p. 280-308). With pigeons, hens, crows, rabbits, cats and dogs, they utilized the principle of food placed in one of two feeding bowls which stood side by side at the gap behind a screen. When an animal starts to eat the food, both bowls were moved in straight lines in opposite directions. After covering a distance of 20 cm, they disappeared behind non-transparent flaps. To solve the problem, the animal had to run around the screen on the side behind where the feeding bowl had disappeared. Their animals had success rates of: pigeons (7%), hens (52%), crows (86%), rabbits (27%), cats (86%) and dogs (89%). We adapted Krushinsky's technique to farm animals so as to provide a slow-moving trolley carrying food within a large animal learning maze. It disappeared into an A frame tunnel and, after certain periods of time, reappeared at the other end.

Three dairy cows were tested. When the food trolley moved, they demonstrated a "startle" reaction (staring at the object with front feet firmly planted) which may have inhibited the learning process. It took them two weeks before they learned to continue eating from the moving food box and anticipate the reappearance of the trolley. After our presence was removed, success came about by observing the cows with a TV monitor. The cows had become conditioned and dependent upon us expecting us to remove them from the testing arena after the food disappeared. They explored and solved the problem *only* after we were out of sight. Since cows learn from each other, each cow and later each bull were put in the testing arena separately. Earlier, another 10 to 11 cows "startled" when the food object started moving and they did not learn how to solve the problem.

None of eight dairy bulls (four Jersey and four Friesian) learned to anticipate and had a larger startle response than cows. They stopped eating once the food box was set in motion. They showed a startle reaction when the trolley was 9 to 10 m

away from them. A study of spatial distances between animals and between a particular animal to a small mechanical moving object in the field was undertaken with the same dairy bulls. Bulls will stand quietly without fighting if greater than 6 m apart; then at about 5-6 m the bulls would back away (as this inaminate object had violated their body space) with escape at a distance of 3 m.

In addition, 12 out of 15 pigs were able to "extrapolate" from a known situation within 3 days, and six out of seven rams tested in 4 days.

Localization of Glycoproteins in Prepubertal Mouse Ovaries. LARRY R. GANION, Department of Physiology and Health Science, Ball State University, Muncie, Indiana 47306.——Glycoproteins serve a variety of functions in biological tissues. To localize glycoproteins associated with ovarian follicles, ovaries from prepubertal, HS, mice were rinsed in Tyrode's solution, bisected, cultured at 37°C *in vitro* in BGJB medium containing H^3 glucosamine (500 μCi/ml) for 13-180 minutes. Next, the tissues were rinsed and fixed for 2 hours in 3% glutaraldehyde in 0.1M phosphate buffer (pH 7.2). After postfixation in 1% osmium tetroxide buffered with 0.1M phosphate buffer (pH 7.2) for 1 hour, the tissues were dehydrated in a graded series of alcohols, treated with propylene oxide and embedded in Epon 812. Thick epon sections were prepared, coated with Kodak NTB-2 emulsion and exposed for 4-6 weeks. Ultrathin sections were cut, transferred to celloidin—coated slides, stained with 2.5% aqueous uranyl acetate, carbon coated, coated with Ilford L-4 emulsion and stored for several months. After development in Dektol and Microdol-X respectively, the thick sections were stained with basic fuchsin and the ultrathin sections were transferred to grids for viewing with an RCA electron microscope. As revealed by examination of the light microscope autoradiographs, the most active site of H^3 glucosamine incorporation is the theca, which becomes black with label after 3 hours of culture. With the electron microscope, silver grains are seen associated with the endoplasmic reticulum and Golgi bodies of thecal cells. The collagen fibers situated between thecal cells are also labeled. In the smaller unilaminar ovarian follicles, most of the label is associated with the follicular envelope. In some of these follicles, as evidenced by electron microscopy, the zona pellucida is noticeable tagged with H^3 glucosamine. Both the oocyte and follicle cells of multilaminar ovarian follicles readily incorporate H^3 glucosamine. Frequently, the zona of such follicles is extensively labeled. Of interest is the association of label with the chromatin of thecal and follicular cell nuclei. These data indicate that glycoproteins are major constituents of the mammalian ovarian follicle. Further, it is speculated that the collagen of the theca is elaborated by the theca cells and the zona is a product of both the follicular envelope and oocyte.

Effects of Triamcinolone Acetonide on the Metabolism of Phenolic Compounds in the Adult Female Mouse. R. R. HALL and K. L. ESBENSHADE, Indiana University—Purdue University at Fort Wayne, Fort Wayne, Indiana 46805.——In the first of three experiments, sixty mature, female, ICR mice were randomly divided into a treated (n = 30) or control group (n = 30). The mice in the treated group received 80 ug triamcinolone acetonide (TA) at -4 and 0 hr. Each group was further divided into 5 subgroups consisting of 6 mice each and given 0.12, 0.15, 0.19, 0.24 or .29 mg p-cresol suspended in oil per g body weight at 0 hr. All substances were given IP. The LD_{50} for control and TA-treated animals was 0.19 and 0.15 mg/g, respectively. The rate of excretion of phenolphtalein (P) after an IP administration was examined in experiment 2. Six female mice served as controls and six others were given 100 ug TA at -12 and 0 hr. All animals received 5 umoles P at 0 hr, placed into metabolism cages and feces and urine collected at 4, 10 and 24 hr. Urine

and homogenized feces were divided into two aliquots. One aliquot was incubated with 500 Fishman Units B-glucuronidase for 60 min. at 37°C. P was determined spectrophotometrically on both aliquots following extraction with ether. The accumulative amount of unconjugated P and P-glucuronide excreted in the urine at times 4, 10 and 24 hr for control was 280, 530 and 1170 and 2100, 3080 and 3930 and for TA-treated was 170, 550 and 1040 and 1220, 1410 and 2850 nmoles, respectively. In experiment 3, 8 mature, female mice were randomly divided into a control (n = 4) or a treated group (n = 4) to observe the effect of TA on uridine diphosphoglucuronyl transferase (UDP-GT) activity. The animlas in the treated group were given 80 ug TA twice daily for 2 days. A hepatic homogenate was prepared from each animal and incubated at 37°C with 75mM maleate buffer (pH 6.4), 0.05% trition X-100, 0.5mM p-nitrophenol and 1mM UDP-glucuronic acid. Aliquots were taken at 20 min intervals and analyzed for p-nitrophenol. The UDP-GT activity in control and TA-treated animals was 115 ± 14 and 59 ± 13 nmole/hr/mg tissue ($\bar{X}$ ± SE), respectivity. The results indicate that TA, a synthetic glucocorticoid, retards the glucuronide conjugation of phenolic compounds.

Fine Structure of the Pig Harderian Gland. MOHINDER S. JARIAL, Department of Physiology and Health Science and Muncie Center for Medical Education, Ball State University, Muncie, Indiana 47306——The Harderian gland of the adult pig is distinctly separated from the more superficial nictitans gland of the third eyelid and is located inferolaterally deep in the orbit in close proximity to the periorbita.

Histologically the Harderian gland of the pig is a tubuloacinar gland composed of serous acini and ducts. Based on the density of the cytoplasmic matrix, two cell types can be distinguished in the acini and intralobular ducts, i.e., "dark" and "light" cells. The dark cells in contrast to light cells contain extensive granular endoplasmic reticulum and dilated smooth enodplasmic reticulum, numerous Golgi complexes, PAS positive granules of different densities and vacuoles in the cytoplasm. Both the dark and light cells contain numerous mitochondria and dense bodies and their luminal surfaces have few, short microvilli. The lateral plasma membranes of both cell types are joined by occluding junctions and often contain intercellular channels lined with microvilli. The myoepithelial cells are often present in relation to both cell types. The intralobular ducts are lined with dark and light cells, which appear structurally similar to those of the acini, but contain relatively fewer secretory granules. Since the dark and light cells of the acini and ducts differ only in the amount of endoplasmic reticulum, Golgi complexes and the number of secretory granules, it is suggested that they represent different functional stages of a single secretory cell type.

In the acinar portion of the gland numerous granules, dense bodies and vesicles mainly from the dark cells are secreted in whole and retain their membranes after extrusion into the acinar lumina. Since cytoplasmic fragments have been observed in the ductal lumina, it appears that the secretion there is liberated by the apical extrusion and fragmentation of the ductal cells.

In conclusion, the Harderian gland of the pig is a typical serous gland which has an "apocrine" mode of secretion.

Mebendazole Therapy of Enteral Trichinellosis in Mice. R. O. MCCRACKEN, A. GARCIA, and H. G. ROBINS, Department of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46205.——Recent reports have demonstrated the chemotherapeutic effectiveness of a benzimidazole anthelmintic, mebendazole, in the treatment of *Trichinella spiralis* infections in rats and mice.

Because mebendazole (methyl 5-benzoyl-2-benzimidazolecarbamate) is used for the treatment of other helminthoses in man, and because it is highly active against enteral and parenteral forms of *Trichinella* in laboratory animals, this compound is one of great potential utility in the treatment of human trichinellosis. However, there have been comparatively few studies of the susceptibility of *T. spiralis* to mebendazole treatment during the enteral phase of infection or of the efficacy of dosage regimens similar to those used in man. Data published by Fernando and Denham (1976, J. Parasitol. 62: 874-876) and McCracken (1978, J. Parasitol. 64: 214-219) suggested the possibility that, as with thiabendazole, parbendazole, and cambendazole, the *Trichinella* population becomes progressively less susceptible to anthelmintic treatment as the worms mature in the gut. For example, a single oral dose of mebendazole at 50 mg/kg 7 hr after inoculation eliminated approximately 95% of the immature worms; the same dosage was only moderately, but significantly active at 72 hr after inoculation when the larvae would have become adults.

We sought here a treatment regimen with mebendazole that would be effective against the drug-resistant adult worms. Mebendazole proved to be highly effective against adult *T. spiralis* in a 3-day treatment course during the intestinal phase of experimental trichinellosis in mice. When treatment began 72 hr after the mice were infected with parasites, the number of adult worms recovered from the host intestine was greatly reduced (93%) by twice daily oral doses of mebendazole at 7.5 mg/kg body weight. (Supported in part by a summer faculty fellowship from the Purdue Research Foundation to R. O. McCracken)

Effects of Prolonged Starvation of Male *Ambystoma tigrinum* in Post-Reproductive Condition. ERIC D. MOULD and DAVID M. SEVER, Department of Biology, Saint Mary's College, Notre Dame, Indiana 46556.——Anorexia and involuntary starvation represent a significant component of the life history of *A. tigrinum*. We investigated the effects of extended starvation upon male *A. tigrinum* by maintaining them in aquaria without food for a period of up to 70 days. Lipase activity increased significantly during each of the first four weeks of starvation. At 35 days lipase activity reached a maximum level and did not increase in the animals starved for 70 days. Hepatic glycogen steadily decreased from an average value of 3.32g glycogen/100g liver at the time of capture to less than 0.50g glycogen/100g liver after 70 days. Visable fat body content varied erratically for the samples of this study and showed no clear pattern except for the very significant reduction in mean fat body weight from the time of capture to the 70 day measurements. Body weight decreased to 45.5% of the initial weight during the study but, as was the case for fat body, did not show a sequential decrease among samples. Gonadal tissue was catabolised from 1.64% of body weight to 0.25% of body weight within 21 days of starvation and shows no further reduction as a percentage of body composition. Although absolute liver weight decreased during the study, it remained an extremely consistent 2.66 ± 0.22% of body weight throughout the entire study.

A Preliminary Study of the Effects of Sidestream Smoke on Postnatal Development and Growth in Mice. JAMES M. REYNOLDS AND CHARLES E. MAYS, Department of Zoology, DePauw University, Greencastle, Indiana 46135.——Female albino (COX-SWISS) mice were exposed to sidestream smoke, and the effects on postnatal development and growth of their offspring were studied. Experimental female mice were placed in a 3.0 cm x 20.5 cm x 25.0 cm perforated plexiglass box and ex-

posed to the smoke of one filter cigarette (Marlboro, softpack) until it had burned to the filter. This method of delivering tobacco inhalants, referred to as complete chamber exposure, took approximately 15 minutes. An additional 30 minutes was allowed for the smoke to clear from the box. After the 45 minute period, the mice were returned to their cages. Smoking of the experimental females began on the same day that they were paired with a male, and was continued once each day until they gave birth to their litters. Control female mice were placed in a similar box for 45 minutes but were not exposed to a burning cigarette. After parturition, the mothers were allowed to nurse their young, undisturbed, until weaning them at day 21. Approximately one month after weaning, both experimental and control mothers were followed through a second litter under the same conditions as those used for the first litter.

Control mice had an average of 11.8 progeny per litter, whereas the average litter of the experimental mice was 8.6 progeny. Percent survivorship at day 21 (weaning) was determined. An average of 9.6 control mice out of the mean litter size of 11.8 survived to weaning, resulting in an 81 percent survivorship. Experimental mice had only a 72 percent survivorship with an average 6.2 progeny out of a mean litter size of 8.6 surviving to weaning. The male to female sex ratios at weaning were 1:00 (46.0%): 1.17 (54.0%) for the control mice and 1:00 (48.8%): 1.05 (51.2%) for the experimental mice. No significant differences were noted in the growth data. However, the control mice were slightly larger than the experimental mice at birth and the experimental mice were slightly larger at weaning. The latter may be caused in part because there is an average of 3.4 more control mice than experimental mice at weaning. This may create a greater amount of progeny competition for milk. In addition, there was a greater percentage of experimental males than control males that survived to weaning, and male mice are generally larger than female mice. These data indicate that sidestream smoke causes reduced litter sizes and lower percent survivorship in COX-SWISS mice.

The Subspecies of the North American Brown Creeper. J. DAN WEBSTER, Department of Biology, Hanover College, Hanover, Indiana 47243.——Thirteen races are recognizable; they are differentiated by color, wing length, and bill length. Geographical variation is clinal, with abrupt steps at a few lines. Migration is fairly regular over long distances in the eastern race, but altitudinal or irregular as to distance and direction in the western and southern Appalachian races. The Mexican and Central America races are resident. A suggestion by a student of bird songs that there may be sibling species in North America led to a search for possible differentiating morphological characters; none were found.

Investigation of Maternal Pheromones in *Octodon degus*. PAMELA J. WHITE, ROBERT B. FISCHER, and GARY F. MEUNIER, Ball State University, Muncie, Indiana 47306.——*Octodon degus* are diurnal hystricomorph rodents, precocial at birth and inhabit a complex system of burrows with a social organization based on group territories. The young are apparently reared by several females in a common nest. The focus of this experiment was to investigate the possibility that infant degus respond to maternal olfactory cues. The first study examined whether degu pups recognize a lactating female. The infants did not show a preference for bedding from a novel lactating female when allowed to choose between it and bedding from either their lactating mother, a novel non-lactating female, a male, or unsoiled bedding. The second experiment investigated whether they would discriminate between their lactating mother and a novel lactating female when each was present in the situation. Given this choice, the degu pups spent significantly more time in

proximity to the novel female. The basis for this choice is unknown but may be related to their extreme precocity. Also, because the young are reared in communal nests, they may not be under any selection pressures to discriminate between mothers. This idea is aided by the fact that the degu shares its burrow system with a separate genus *Abrocoma bennetti*.

Diurnal Movement of Fish Larvae and Invertebrates into a Power Plant Intake

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Introduction

Kelso and Milburn (1979) analyzed the impingement and entrainment occurring during 1975 or 1976, as a result of the once-through cooling process, to attempt to determine the relevance of this loss to the Great Lakes fishery. They determined that impingement losses, when combined with entrainment losses will affect recruitment to some unknown degree and will likely constitute a significant undesirable impact upon the Great Lakes fishery. They indicated data were available for only about 24% of existing plants and few sources provided acceptable data sets with identification of major species and year-round sampling. They did not discuss diurnal or depth differences in entrainment rates for fish larvae or invertebrate groups.

While complying with the National Pollutant Discharge Elimination System (NPDES), Part 1B(8), Permit Program, The Detroit Edison Company, Detroit, Michigan, undertook an intake entrainment study at their Monroe Power Plant. One aspect of the study was to determine if any differences existed in entrainment rates of fish larvae and invertebrates between periods of daylight and darkness and the 1 and 3 m levels in the intake channel. This paper will present the results of sampling from December 1975 to December 1976 to determine diurnal and depth differences in entrainment rates of fish larvae and invertebrate groups.

Study Location

The Monroe Power Plant is a 4 unit, coal-fired electric generating station with a maximum expected net capacity of 3,150 Mwe (megawatts). It is located on the western shore of Lake Erie just south of the confluence of the Raisin River between Brest and LaPlaisance bays. The plant is approximately 61 km southwest of Detroit, Michigan, and 27 km northeast of Toledo, Ohio. Water used for the once-through cooling is drawn from the Raisin River through a 213 m long, 11 to 33 m wide, intake canal. The canal branches to provide water to two identical 8 bay screen houses each servicing 2 units (Figure 1). The depth of the intake canals varied with normal, high and low water flow and low wind tide from 6.9 m, 5.3 m and 3.1 m, respectively.

Methods and Materials

Eight 530 l/min Kenco Model 139 submersible sump pumps were fitted with 5.1 cm diameter flexible hoses and water was pumped through a 1-x-3 m oceanographic plankton net with mesh size of 571μ. The samples were collected from 6 AM to 6 PM and 6 PM to 6 AM from pump locations B, C, D, E, F and G (Figure 1). A 1.5 m head was usually maintained and provided a measured flow of approximately 530 l/min. This flow yielded a 381,600 liter sample for each 12-hour period. The samples were removed after 12 hours, preserved with 10 percent formalin and returned to the laboratory for sorting and identification.

All entrained fish were categorized as egg-larvae, yolksac larvae, larvae or prejuveniles. To facilitate data reduction the first category was considered as

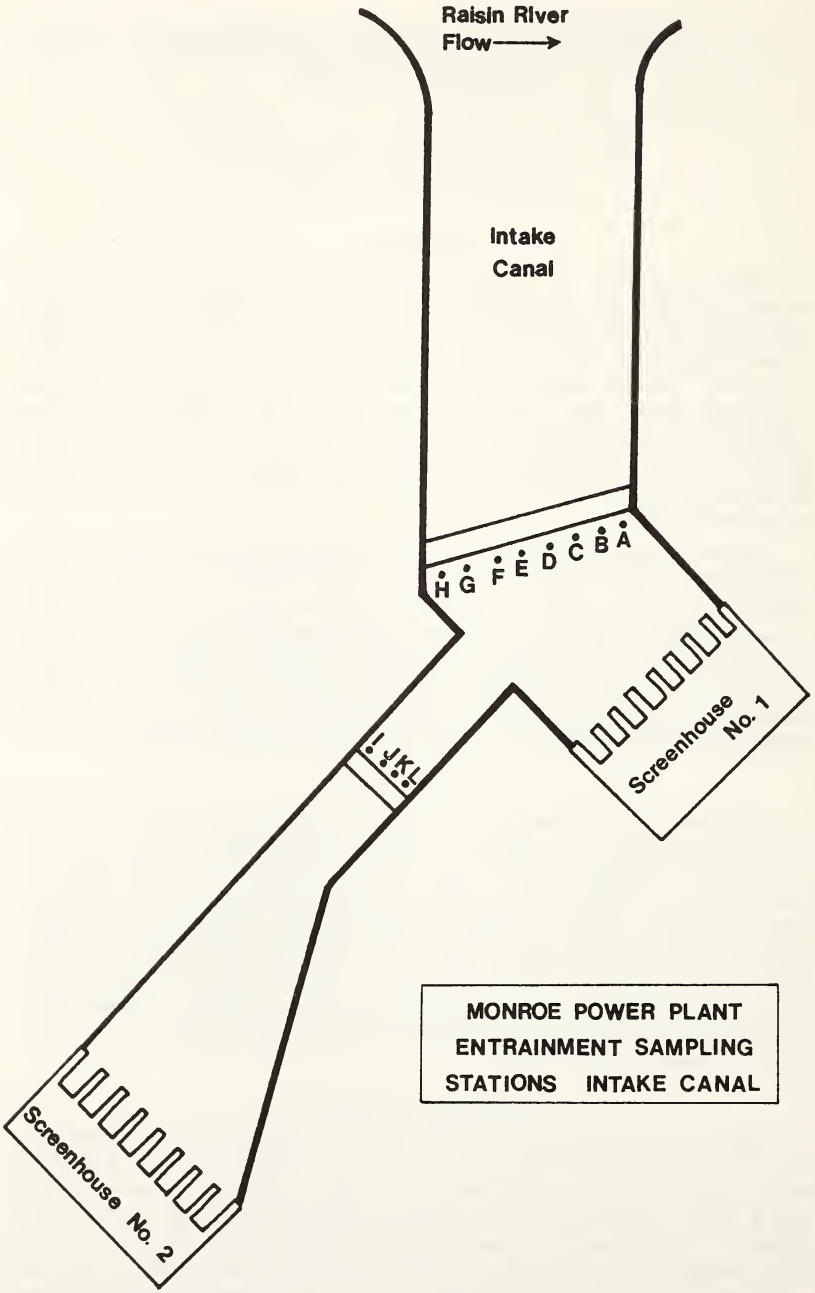
Raisin River
Flow
Intake
Canal
H G F E D C B A
I J K L
Screenhouse No. 1
Screenhouse No. 2
MONROE POWER PLANT
ENTRAINMENT SAMPLING
STATIONS INTAKE CANAL

FIGURE 1.

"eggs", and the last two as "larvae". Yolksac larvae were retained as a separate category.

The SAS statistical package GLM analysis of variance program and Duncan/Waller multiple comparison test was used to determine if significant diurnal periods and diurnal period x depth interaction differences occurred for fish larvae and invertebrate groups.

Results and Discussion

Table 1 presents the difference in mean 12 hour collections for combined land 3 m samples. There were significant differences in collections for 6 of 11 categories of fish larvae. In these categories there were significantly higher numbers of yolksac larvae and larvae collected during the 6 PM and 6 AM period than the 6 AM to 6 PM period. Although significantly more perch, *Perca flavescens*, yolksac larvae were collected between 6 AM to 6 PM there was no significant difference between periods for perch larvae. There were also no significant differences between periods for Clupeidae (alewife, *Alosa pseudoharengus*, and gizzard shad, *Dorosoma cepedianum*), yolksac larvae smelt, *Osmerus mordax*, walleye, *Stizostedion canadense*, carp, *Cyprinus carpio*, and channel catfish, *Ictalurus punctatus* yolksac larvae and larvae.

TABLE 1. *Comparison of diurnal differences in mean 12 hour entrainment rates for fish larvae and invertebrate groups at the Monroe Power Plant, Monroe, Michigan. (PM and AM represent 6 PM to 6 AM and 6 AM to 6 PM, respectively).*

	Total yolksac larvae		Total invertebrates	
Time period	PM	AM	PM	AM
Number of samples	57	33	108	105
Mean	15.3	6.8	105.5	15.5
	Total larvae		Chironomid larvae	
Time period	PM	AM	PM	AM
Number of samples	60	39	93	76
Mean	31.9	11.5	9.6	6.2
	Total yolksac larvae and larvae		Chironomid pupae	
Time period	PM	AM	PM	AM
Number of samples	66	48	97	84
Mean	44.2	14.0	96.1	9.3
	Clupeidae larvae		*Gammarus* spp.	
Time period	PM	AM	PM	AM
Number of samples	51	29	68	37
Mean	36.0	13.5	4.6	2.1
	Perch yolksac larvae		*Chaoborus* spp.	
Time period	PM	AM	PM	AM
Number of samples	16	9	26	11
Mean	5.4	2.8	16.7	3.2
	Perch larvae		Ephemeroptera	
Time period	PM	AM	PM	AM
Number of samples	10	20	42	20
Mean	2.5	2.0	3.0	1.6
	Carp yolksac larvae		Trichoptera	
Time period	PM	AM	PM	AM
Number of samples	50	25	32	31
Mean	14.7	6.8	3.6	3.6

There were significant differences in collections for 6 of 8 categories of invertebrates. In these categories there were significantly higher numbers of invertebrates collected during the 6 PM to 6 AM period than the 6 AM to 6 PM period. There were no significant differences between periods for Trichoptera and Odonata groups.

Table 2 presents the differences in mean 12 hour collections for diurnal period x depth interaction. Significant differences are displayed utilizing underscoring of the same or different mean values. In the category total yolksac larvae *17.4 13.4 8.1 5.1* indicates *17.4* and *13.4* are significantly different from each other and from 8.1 and 5.1 (at $P \leq 0.05$ level). The single underscore beneath *8.1 5.1* indicates that although the values are significantly different from *17.4* and *13.4* they are not significantly different from each other. In all categories of yolksac larvae and larvae, significantly greater numbers were collected during the 6 PM to 6 AM period. Total yolksac larvae showed significantly larger numbers were collected in the 3 m samples while for total larvae significantly higher numbers were collected in the 1 m samples. When both these categories were combined there was no significant difference between depths. There were no significant differences in col-

TABLE 2. *Comparison of diurnal x depth interaction differences in mean 12 hour entrainment rates for fish larvae and invertebrate groups at the Monroe Power Plant, Monroe, Michigan. (PM and AM represent 6 PM to 6 AM and 6 AM to 6 PM, respectively).*

	Total yolksac larvae				Total invertebrates			
Time period	PM	PM	AM	AM	PM	PM	AM	AM
Depth (m)	3	1	3	1	3	1	3	1
Number of samples	27	30	19	14	54	54	53	52
Mean	17.4	13.4	8.1	5.1	120.5	90.5	19.9	10.9
	Total larvae				Chironomid larvae			
Time period	PM	PM	AM	AM	PM	PM	AM	AM
Depth (m)	1	3	3	1	3	1	3	1
Number of samples	29	31	19	20	48	39	45	37
Mean	38.0	26.1	12.1	11.0	12.1	7.6	7.0	4.8
	Total yolksac larvae and larvae				Chironomid pupae			
Time period	PM	PM	AM	AM	PM	PM	AM	AM
Depth (m)	1	3	3	1	3	1	3	1
Number of samples	34	32	23	25	47	50	43	41
Mean	44.3	39.9	16.6	11.6	107.3	85.6	11.9	6.7
	Clupeidae larvae				*Gammarus* spp.			
Time period	PM	PM	AM	AM	PM	PM	AM	AM
Depth (m)	1	3	1	3	3	1	3	1
Number of samples	25	26	14	15	38	30	23	14
Mean	42.5	29.7	14.8	12.3	6.0	2.8	2.3	1.7
	Carp yolksac larvae				*Chaoborus* spp.			
Time period	PM	PM	AM	AM	PM	PM	AM	AM
Depth (m)	3	1	3	1	3	3	1	1
Number of samples	23	27	14	11	11	6	15	5
Mean	15.9	13.7	7.3	5.5	34.6	4.5	3.6	1.6
					Ephemeroptera			
Time period					PM	PM	AM	AM
Depth (m)					3	1	3	1
Number of samples					26	16	14	6
Mean					3.3	2.4	1.7	1.3

lections for diurnal period x depth interaction for smelt, walleye and channel catfish yolksac larvae or larvae and carp larve.

In all categories of invertebrates significantly greater numbers of invertebrates were collected during the 6 PM to 6 AM period and, except for Ephemeroptera, the 3 m depth samples collected significantly higher numbers of invertebrates than the 1 m depth. There were no significant differences for Trichoptera and Odonata groups.

Conclusions

Kelso and Milburn (1979) estimated annual entrainment rates for each Laurentian Great Lake based upon a derived regression formula between power plant size and number of larvae entrained and found it to be relatively strong ($r = 0.63$). They stated that it is apparent that numbers entrained increased with increasing power plant size and although local deviations may exist, entrainment is in direct relation to plant size and consequently cooling water volume. While I don't dispute this rationale, I suggest that based upon the data presented in this paper concerning differences in diurnal periods and diurnal periods x depth sampling that the use of annual entrainment rates for a single plant, much less for an entire lake, could be misleading unless these local deviations are taken into consideration during the calculations.

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First Records of the Smoky Shrew, *Sorex fumeus*, and Pygmy Shrew, *Microsorex hoyi*, from Indiana

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Introduction

Sorex fumeus Miller is a wide-ranging species occurring from southeastern Canada through the northeastern United States as far south as the mountains of Georgia and west across two-thirds of Kentucky (Caldwell and Bryan, in prep; Hall, 1981). *Microsorex hoyi* (Baird) ranges from Alaska throughout Canada and the northern tier of the United States, and generally overlaps the range of *S. fumeus* in the eastern United States (Diersing, 1980). Apparent isolated populations have been reported from southern Illinois (Diersing, 1980) and western Kentucky (Caldwell and Bryan, in prep). However, neither species was previously known from Indiana, although we have suspected for some time that *Microsorex hoyi* occurred there. Caldwell and Bryan (in prep) recently took both of these species just to the south of Indiana in Breckinridge County, Kentucky.

Microsorex hoyi was previously taken in the Western Coal Field and Drippings Springs Escarpment of Kentucky (Caldwell and Bryan, in press). The former is of Pennsylvanian sandstone, the latter of Mississippian limestone (McFarland, 1943). The Coal Field is the Kentucky section of the much larger Eastern Interior Basin, which occurs in portions of Illinois, Indiana, and Kentucky. The interior region of the basin is bounded by the Pottsville Escarpment in Kentucky. The Pottsville and Dripping Springs Escarpments continue north into Indiana as the Crawford Uplands and Mitchell Plain respectively (Malott, 1922). It was because of this continuous nature of the physiographic-ecological region that trapping was carried out in southern Indiana.

The main purpose of this paper is to report the occurrence of these species in Indiana.

Methods and Materials

Twenty-four pitfall traps (sunken cans) were set in Harrison-Crawford State Forest, Harrison County, Indiana, on 1 May, and twelve additional ones were set in Crawford County on 22 August 1981.

Cans were sunk at the bases of rotting stumps, against large boulders and rockfaces, and near fallen logs, usually flush against natural barriers. Snap-traps were also used, and these were set along similar objects.

Results and Discussion

On 31 May 1981, the pitfalls in Harrison County were checked. Traps contain-

ed one Pygmy Shrew, *Microsorex hoyi* (ISU 5408), and ten Smoky Shrews, *Sorex fumeus* (ISU 5409-5418). These are the first records of these species in Indiana. Standard measurements for the Pygmy Shrew were 74 mm total length, 24 mm tail length, and 8 mm hind foot. The average measurements for the ten Smoky Shrews were 104.4 mm, 40.9 mm, and 12.7 mm. An additional Pygmy Shrew, but no Smoky Shrew, was taken on 8 September 1981 at the Crawford County site. This site was at the mouth of the Stinking Fork of the Blue River.

Habitat. The forests at both sites were mesic to dry-mesic north-facing upland situations. Canopy dominants included sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), northern red oak (*Quercus rubra*), white ash (*Fraxinus americana*) and white oak (*Q. alba*).

Microsorex hoyi has been taken in a variety of habitats in Kentucky including mesic to dry situations and upland to low areas along streams (Caldwell and Bryan, in prep). *Sorex fumeus* is most often found in mature mesic forests with deep organic litter (Hamilton, 1940). This is the situation at the Harrison County site. The average basal area estimate for 7 stations along the trap line at Harrison County was 31 m^2/ha. Mammal burrows in the humus and upper soils were numerous.

Species Associates. Blarina brevicauda, Cryptotis parva, Microtus pinetorum, and *Peromyscus leucopus* were also taken, the last species usually when the pitfalls were filled with water. *Cryptotis parva* was taken with *M. hoyi* at the Crawford County site. In upland situations in western Kentucky, Caldwell and Bryan (in prep) have captured *S. longirostris* in association with *S. fumeus* and *M. hoyi*, and it likely occurs at the southern Indiana sites.

Taxonomy of Microsorex. Long (1972) recognized two species of *Microsorex*: *M. hoyi*, a northern animal occurring west of the St. Lawrence River, and *M. thompsoni*, occurring in the nothereastern United States and south to Georgia. Long believed the eastern *M. thompsoni* contained two subspecies, the nominate form and *M. t. winnemana.* Diersing (1980) has recently revised the pygmy shrews. He has relegated *Microsorex* to subgeneric status under the Holarctic genus *Sorex*. It was viewed as containing one species, *Sorex hoyi*, with five subspecies. Hamilton and Whitaker (1979) and Hall (1981) treat pygmy shrews as genus *Microsorex*, and we follow this taxonomic assignment.

Table 1 shows selected measurements of *M. hoyi* from Kentucky, Indiana, and southern Illinois, but unfortunately there are few specimens from the western part of the range.

TABLE 1. *Means ± 1 SD of selected external and cranial measurements in mm from southern Illinois, western Kentucky-Indiana, and eastern Kentucky.*

n =	Illinois 1	West KY-IN ± 1 SD 9	East KY ± 1 SD 12
Total Length	–	67.83 ± 3.19 (6)	74.60 ± 2.88 (5)
Body Length*	–	44.83 ± 2.64 (6)	49.60 ± 1.95 (5)
Tail Length	–	23.25 ± 1.28 (8)	26.33 ± 1.94 (9)
Maxillary Breadth	3.9	3.80 ± 0.07 (9)	3.82 ± 0.11 (12)
Molariform Tooth Row Length	3.3	3.15 ± 0.05 (9)	3.19 ± 0.10 (12)
Unicuspid Tooth Row Length	1.5	1.3 ± 0.09 (9)	1.37 ± 0.12 (12)
Condylobasal Length	12.7	12.7 ± 0.15 (9)	12.89 ± 0.23 (10)
Relative Condylobasal Length	–	0.19 ± 0.01 (6)	0.17 ± 0.01 (4)

*In Diersing 1980, the column labeled as total length is actually body length, so this variable is included for comparison. (n = total number of specimens examined from each area.)

Mean values for body length, tail length, and condylobasal length of the eastern Kentucky individuals are very close to the measurements of *M. hoyi winnemana* given by Diersing (1980). These are respectively 50.3 vs. 50.6, 26.8 vs. 27.4, and 12.9 vs. 12.9 mm. Based on these measurements the eastern Kentucky population appears to be assignable to *winnemana*. The western Kentucky-Indiana measurements do not appear to fit any of the subspecies listed by Diersing (1980), but are just slightly lower than for the southern Illinois specimens. This perhaps suggests a north-south cline through Illinois with specimens reaching their minimum size at the southern terminus of their range in western Kentucky.

Diersing (1980) does not believe the southern Illinois population is in contact with the northern Illinois population. He suggests the prairie peninsula may act as an isolating mechanism, but additional field work is needed. If intervening populations are found and a cline does exist, it would seem to indicate only one variable subspecies, *M. h. hoyi*, in the eastern United States. If no intervening populations are found, then the western Kentucky-Indiana populations are probably isolated from *M. h. hoyi* and *M. h. winnemana* and should receive subspecific status. This problem is currently under investigation by Caldwell and Smith.

Data are now being collected on distribution, food habits, ectoparasites, and reproduction of these species in Indiana.

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Daily Cycles in Serum Cortisol Levels in the Bluegill (*Lepomis macrochirus*): Effect of Temperature

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Introduction

Daily fluctuations in serum corticosteroid homrone levels have been demonstrated in several species of teleosts (channel catfish, *Ictalurus punctatus*, Boehlke et al. (1); Gulf killifish, *Fundulus grandis*, Garcia and Meier (4); carp, *Cyprinus carpio*, Redgate (6); goldfish, *Carassius auratus*, Singley and Chavin (7); Peter et al. (5)). However, Delahunty et al. (2) found that the response to photoperiod varied with season as they found photoperiod had no affect on serum corticoids during July. Strange et al. (8) found no evidence of diurnal cycles in corticoid levels in chinook salmon. Also data presented by Donaldson and Dye (3) are not indicative of the presence of a diurnal cycle in corticoids of sockeye salmon. It could well be, as suggested by Strange et al. (8), that between fish variation in corticoids of salmonids precludes detection of a rhythm.

While sudden changes in water temperature has been shown to affect cortisol in teleosts (8), the effect of different acclimation temperatures on diurnal cortisol cycles has not been established. Peter et al. (5) studied daily cycles in serum cortisol levels in goldfish in response to both photoperiod and temperature. The lack of any common pattern in the cortisol cycles under either cold (12°C) or warm (21°C) temperatures led these workers to suggest that temperature is not an important synchronizer.

The objective of this study was to determine if serum cortisol in bluegill, *Lepomis macrochirus*, exhibits a diurnal cycle and what effect acclimation temperature might have on such a cycle.

Materials and Methods

Young bluegill (sexually immature) were captured with minnow traps from St. Mary's Pond. The fish were transported to Indiana University at South Bend's animal holding facilities and placed in large aquaria (150 gallon). Fish were acclimated to a 12 hour light 12 hour dark photoperiod for at least two weeks prior to acclimation to experimental temperatures. The fish were then allowed to acclimate to either 20°C or 5°C water temperatures for at least two weeks prior to the experiments. Fish were fed Purina trout chow daily until 24 hours before sampling.

Blood samples were taken every 2 hours for a 48 hour period. Fish were netted from the aquarium with as little disturbance as possible to the remaining fish and placed into a tricane methane sulfonate anesthetic solution (1:1000). Blood samples were taken from fish while under deep anesthesia by severing the caudal peduncle and collecting the blood in heparinized capillary tubes.

Serum cortisol was determined on pooled serum (10-15 animals) by a modification of the fluorometric method described by Wedemeyer and Yasutake (11). Cor-

tisol from 100-200 μ 1 of serum was extracted into dichloromethane and extensively purified. The extracted cortisol was treated with a sulfuric acid-ethanol (3:1) mixture and the cortisol-sulfuric acid-ethanol solution's fluorescence measured in a fluormeter with excitation at 470 nm and emission at 550 nm. The same volumes were used for blanks, standards and unknowns to avoid the need for dilution factors in the calculations.

Results and Discussion

The effects of exposure to different environmental temperatures (5° and 20°C) on serum cortisol fluctuations are reported in Figure 1. Significant daily fluctuations in serum cortisol levels occurred in both experimental groups, fish acclimated to 20°C having two daily peaks 12 hours apart while fish acclimated to 5°C had four daily peaks ranging from 4 to 8 hours apart. Several other investigators have reported two daily fluctuations in serum cortisol (2, 4, 7) however, Peter et al. (5) found as many as three daily peaks in goldfish but were unable to show any common pattern in cortisol cycles in either cold (12°) or warm (21°) acclimated fish. The reason for the 4 daily peaks in the cold (5°C) acclimated fish (Figure I) is difficult to assess. Strange (8) studied serum cortisol levels in channel catfish subjected to the stress of confinement at three different acclimation temperatures and found basal concentrations of serum cortisol were partially temperature dependent. However, his data does not suggest a circadian rhythm at any temperature. We do note however, that samples were taken at various time intervals ranging from 3 to 6 hours apart in any one day. Thus, a fluctuation in serum cortisol could have occurred between samples. Peter et al. (5) found no common pattern in the cortisol cycles of goldfish under either cold (12°C) or warm (21°) acclimated fish which lead these workers to suggest that temperature is not an important synchronizer. The adaptive significance of increased cortisol fluctuations in cold acclimated bluegill is not clear although it could be a result of increased stress.

The fish acclimated to the higher environmental temperature had lower basal serum cortisol levels than the fish acclimated to the lower environmental temperature (Figure I). Terkatin-Shimony et al. (10) found cortisol levels to be higher in *Tilapia aurea* acclimated to 17°C than those acclimated to 28°C. It could well be that the differences in serum cortisol levels at these temperatures could be attributed to differences in cortisol clearance rates. Terkatin-Shimony et al. (10) found the $T_{1/2}$ of cortisol in *T. aurea* acclimated to 17°C to be 208 minutes while the $T_{1/2}$ of cortisol in those acclimated to 28°C to be 132 minutes. Thus, if secretion rates of cortisol do not change, the difference in serum cortisol, may be due to differences in clearance rates at the two different acclimation temperatures.

Bluegill acclimated to the lower temperature (5°C) were found to feed quite sparingly and in this respect were in a situation somewhat similar to migrating eels and salmonids. Terkatin-Shimony et al. (10) observed the same behavior in *T. aurea* acclimated to lower temperature and suggested that high cortisol levels in fasting fish probably reflect a physiological stress during which an increased secretion of corticosteroids would be expected, related to the mobilization and metabolism of protein and fats and their conversion to carbohydrates. Peter et al. (5) however, found goldfish had low serum cortisol levels under cold (12°) conditions but under warm (21°C) conditions, they had high levels and large fluctuations. Since it is assumed that the goldfish fed normally at 12°C, this study cannot be directly compared with our results. That high levels of serum cortisol in cold acclimated fish could be attributed to either the high activity of interrenal tissue in fasting fish or to the slow rate of cortisol clearance cannot be excluded. However, the reason for

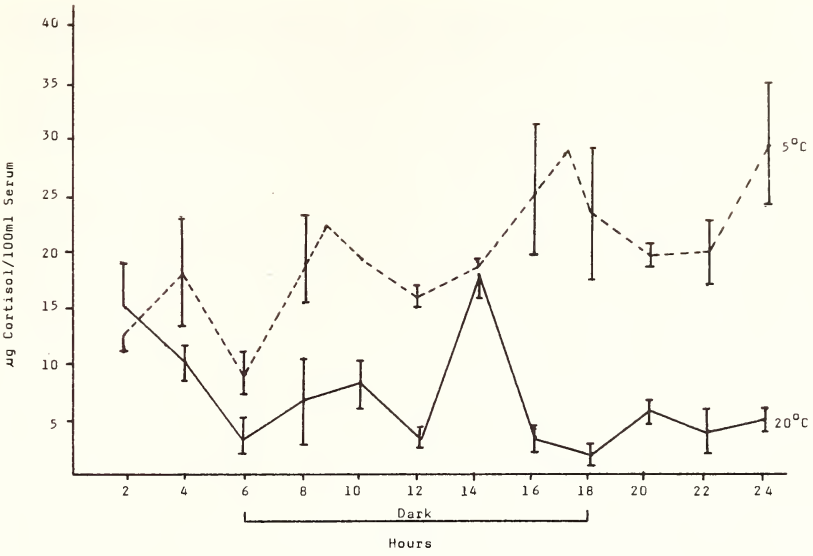

FIGURE I. *Daily fluctuations in serum cortisol levels under different environmental conditions.*

the different pattern in daily cycles in serum cortisol in cold acclimated fish is not known and further work is necessary to confirm the stability of these patterns over long periods.

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Hairy-tailed Mole (*Parascalops breweri*) Remains from South-central Indiana Caves

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Living Hairy-tailed Moles have never been recorded in Indiana. *Parascalops breweri* was on Evermann and Butler's (1894) list of hypothetically occuring Indiana mammals (6). Hahn (1909) cited, but excluded from consideration, two *P. breweri* skins labeled "Bloomington" in the Indiana University collection (12). Lyon (1936) noted that only one of those specimens had a Bloomington label, the other being untagged (17). Those skins are no longer in the Indiana University collection (Dr. Craig E. Nelson, personal communication) and appear to be lost. Some of the "old" Indiana University collection had long been destroyed by dermestids. Other specimens were sent to the Museum of Natural History at the University of Illinois and to the United States National Museum; *P. breweri* skins, however, were not among those materials (letters, Dr. Donald F. Hoffmeister, October 30, 1981 and Michael D. Carleton, November 5, 1981, respectively). Because there were other birds and mammals in the "old" Indiana University collection bearing "Bloomington" labels that could not possibly have come from Bloomington (Dr. Russell E. Mumford, letter October 20, 1981) the mole labels might have likewise been misattributed. Only the Eastern Mole (*Scalopus aquaticus*) has been recovered in present Bloomington area student collecting. *P. breweri* was not listed by McAtee in 1907 (18) nor by Mumford in 1969 (19). The nearest occurrence of *P. breweri* to Indiana is the eastern two thirds of Ohio, southward through Kentucky (Figure 1).

The Hairy-tailed Mole is locally common in woodlands within its range, although it also occurs in open fields. Where it occurs with the Eastern Mole (*Scalopus aquaticus*) it tends to inhabit the woodlands and higher ground, and the Eastern Mole the more open country and lowlands (1; 5). *P. breweri* is active day and night, and will forage outside of its burrow nocturnally (2; 5); because of this, it is an occasional item of owl prey (3). Owl pellets contribute to concentrated deposits of small animal remains in caves (4; 9; 10; 11), perhaps contributing occasional mole bones.

The only previous fossil record of the Hairy-tailed Mole in Indiana was from the Harrodsburg Crevice deposit, Monroe County. Bones of one *P. breweri* (minimum) were associated with remains of 5 extinct mammal taxa (*Canis* cf. *dirus*, Dire Wolf; *Smilodon fatalis*, Sabertooth Cat; *Panthera onca augusta*, Pleistocene Jaguar; *Equus* cf. *complicatus*, Horse, and *Platygonus* cf. *cumberlandensis*, Peccary). Bones of the Spotted Skunk (*Spilogale* cf. *putorius*), Woodrat (*Neotoma* cf. *floridana*), and the Plains Pocket Gopher (*Geomys bursarius*) occurred out of their modern ranges (extralocally). A warmer and drier than present short-grass prairie/forest edge environment of Sangamonian (last interglacial) age was proposed (20; 22).

Recent finds of *P. breweri* bones in Monroe and Lawrence County caves indicate that the mole was, at various times at least, present in south-central Indiana. In Anderson Pit Cave, Monroe County, an isolated ledge deposit (north northwest passage, 334 feet from present cave entrance) contained over 60 vertebrate species of Late Pleistocene-early Recent age. This included a fragmented right ulna, upper

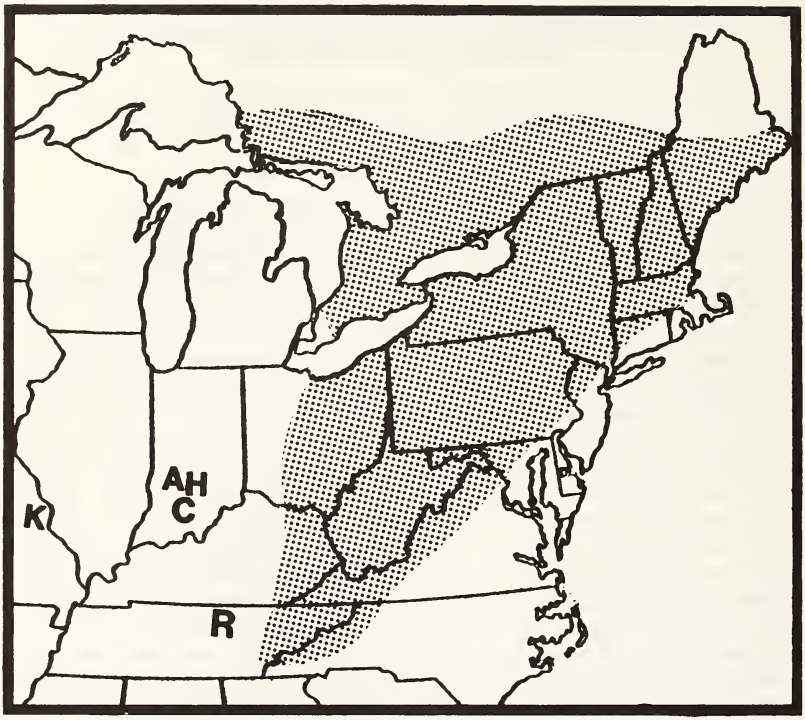

FIGURE 1. *Modern range and extralocal fossil occurrence of the Hairy-tailed Mole,* Parascalops breweri. *Modern range: stippled (data from Hall and Kelson, 1959). Fossil sites: K, Crankshaft Cave, Jefferson County, Missouri; H, Harrodsburg Crevice, Monroe County, Indiana; A, Anderson Pit Cave, Monroe County, Indiana (2 sites); C, Carcass Crypt Cave, Lawrence County, Indiana; R, Robinson Cave, Overton County, Tennessee.*

premolar, upper M3, and a lower molar (Cat. No. 13-964, Figure 2A) of *P. breweri.* Scutes of the Giant Armadillo (*Dasypus bellus*) suggest that the deposit is at least 9,550 years old (16). Extralocal animals included the Smooth Greensnake, *Opheodrys vernalis* (15); the Rice Rat, *Oryzomys* cf. *palustris* (23); the Woodrat, *Neotoma floridana,* and the Thirteen-lined Ground Squirrel, *Spermophilus tridecemlineatus.* Eastern Mole bones (3 individuals minimum) occurred in the upper level of the deposit; *P. breweri* remains were in the lower. A mild-wintered moist climatic period of Late Pleistocene-early Recent age was proposed.

A different ledge deposit in Anderson Pit Cave (south southeast passage, ca. 170 feet from present entrance) produced a travertine encrusted left dentary fragment containing molars 1 and 2 (Cat. No. 13.1-16, Figure 2B). Twenty five extant vertebrate species and floral debris was associated. The Woodrat was the only other extralocal mammal. The deposit is undated.

A *P. breweri* radius (Cat. No. 2-452, Figure 2C) was recovered from Carcass Crypt Cave, Lawrence County, in floor deposits ca. 85 feet inside the pit cave, associated with bones of 35 other vertebrate species, including those of the Eastern

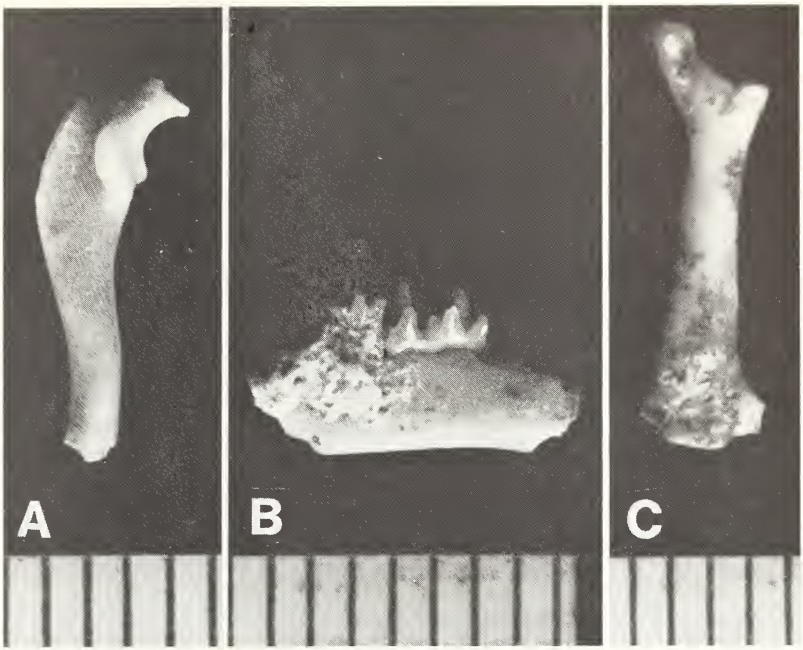

FIGURE 2. Parascalops breweri *remains from Indiana caves: A, Right ulna fragment (Cat. No. 13-964), Anderson Pit Cave; B, Left dentary fragment (Cat. No. 13.1-16), Anderson Pit Cave. Note adhering travertine; C, Radius (Cat. No. 2-452), Carcass Crypt Cave. Scale in millimeters.*

Mole, *S. aquaticus*. Extralocal species included the Woodrat and Spotted Skunk. The Opossum (*Didelphis virginiana*), also recovered, is believed to have entered the region from the south within the past 3 or 4 thousand years (8). Thus, a sub-Recent age is proposed for that deposit.

Two other states have produced extralocal Hairy-tailed Mole fossils (Figure 1). Remains of 15 *P. breweri* (minimum) were recovered from Crankshaft Cave, Missouri. Associated were bones of 7 extinct and several other extralocal mammals. The mixed deposit was thought to have spanned the late glacial to the postglacial warm, dry "xerothermic" period (21).

Remains of 3 *P. breweri* (minimum) were removed from Robinson Cave, Tennessee, along with bones of 5 extinct and several extralocal mammals. A temperate/boreal climate of Wisconsinan (last glacial) age or later was proposed (10).

By its association with extinct and extralocal vertebrates, it is clear that past range adjustments of *P. breweri* were due to climatic/ecological conditions different from those that exist at the fossil sites today. Because the mole presently inhabits cool northeastern climates, it would have expanded its range southward and westward during glacial maxima. Yet its remains also occur with mammals of warmer and/or drier climates (eg. Giant Armadillo; Plains Pocket Gopher); the Harrodsburg Crevice deposit represents a drier, and perhaps warmer, interglacial. "In-

compatible" faunal elements in the Late Pleistocene have been thought by some authors to represent more "equable" climates, where cooler summers and warmer winters might allow integration of boreal, western and southern species (7; 14). However, this Climatic Equability Model cannot fully explain *P. breweri* occurrence in Indiana: the Anderson Pit armadillo site lacks a strong boreal fauna (especially the important shrews and microtine rodents) and the Carcass Crypt remains are only of sub-Recent age. What the fossil faunas do indicate is that *P. breweri* may have had a lingering range reduction following glacial age range expansion. In Indiana the evidence indicates a lingering range reduction from the Illinoian (second to last) Glaciation (in the Sangamonian age Harrodsburg Crevice) and from the Wisconsinan Glaciation (in the Late Wisconsinan-early Recent Anderson Pit armadillo site, and in the sub-Recent Carcass Crypt Cave deposit).

P. breweri bones from Anderson Pit (13-964) are temporarily in the author's collection; all other *P. breweri* material (13.1-16; 2-452) is in the collection of the Indiana State Museum, Indianapolis.

Acknowledgments

I thank Dr. James R. Purdue, Illinois State Museum, Springfield, for the loan of a *P. breweri* skeleton. John E. Guilday, Associate Curator of Vertebrate Fossils, Carnegie Museum of Natural History, Pittsburgh, kindly confirmed *P. breweri* identifications and reviewed this manuscript. David Rieger produced Figures 1 and 2.

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The Occurrence of *Ichthyomyzon castaneus* (Petromyzontidae) in the Saint Joseph River Drainage of Indiana

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Introduction

Marenchin and Sever (3) reported the collection of four specimens of lampreys in a recent survey of the fish of the Saint Joseph River drainage in Indiana. Two were adult individuals of *Lampetra appendix* (= *L. lamottei*), a nonparasitic species. These specimens were collected in the Little Elkhart River, Elkhart County, and represented a new record for the portion of the Saint Joseph River drainage in Indiana (1, 4). The other two specimens were ammocoetes. One specimen came from Christiana Creek and the other from Turkey Creek, both in Elkhart County.

Positive specific identification of ammocoetes of most lampreys is not possible by use of morphological characters alone (8). However, myomere count can eliminate some possibilities (6, 8). The specimen from Christiana Creek (15.1 cm total length) had 50 myomeres while the one from Turkey Creek (9.4 cm TL) had 54 myomeres (3). Based on these counts, the ammocoetes could represent *Ichthyomyzon fossor*, a nonparasitic species, or *I. castaneus* or *I. unicuspis*, both parasitic species (6, 8).

Of these species, there are definite reports in the literature of only *I. castaneus* from the Saint Joseph River drainage (1, 2). Two ammocoetes collected in 1895 from Turkey Creek with 51 myomeres each were questionably listed as *I. unicuspis* by Hubbs and Trautman (2). However, they (2) stated that these specimens were "perhaps *I. fossor*", and Gerking (1) lists this record under both species, with the identification of *I. unicuspis* deemed questionable. There are undisputed records of *I. fossor* and *I. unicuspis* from adjacent drainages (1, 2, 5), so their occurrence in the Saint Joseph River drainage is possible.

This paper reports on further collections of fish at the Christiana Creek locale studied by Marenchin and Sever (3). The primary goal of these collections was to collect adult lampreys so that the identity of the species occurring in that drainage could be established. A secondary purpose of this study was to record additional species beyond the 40 other species of fish reported by Marenchin and Sever (3) from tributaries of the Saint Joseph River in Elkhart County.

Materials and Methods

The locality sampled was a 250 m portion Christiana Creek at T38N R4E, northwestern corner of section 20, Elkhart County, Indiana. Four collections were made. Three collections, on 19 September, 1980, 20 August, 1981, and 18 September, 1981, were made using electrofishing with a Coffelt BP-2 electroshocker as the sole collecting technique. The other collection, on 20 May, 1981, was made using a 190 x 408 cm nylon seine with 6.2 mm square mesh as the only collecting method. All collections were made between 1000-1300 hours. Fish were preserved upon capture in 10% formalin and are currently stored in 60% isopropanol at Saint Mary's College except for one adult lamprey which was deposited in the collections of the Illinois Natural History Survey, Urbana.

Results and Discussion

Lampreys were obtained in the electrofishing collections made on 19 September, 1980, and 18 September, 1981. On the first occasion, two parasitic lampreys were attached to the same side of the lateral body wall of a large *Cyprinus carpio* (ca. 40 cm standard length). These lampreys were 17.9 cm and 18.6 cm TL and had 52 and 51 myomeres respectively. On the second date, a lamprey was collected while attached to the dorsal midline just posterior to the head of a *C. carpio* (27.5 cm SL). This lamprey was 26.3 TL and had 52 myomeres. In addition, four ammocoetes, 7.0-8.8 cm TL and with 50(2), 51 and 52 myomeres, were collected on the latter date by shocking mats of submerged vegetation along shore.

The three lampreys were positively identified as *Ichthyomyzon castaneus*. The other parasitic lamprey likely present, although unconfirmed, in the Saint Joseph River drainage is *I. unicuspis* (1, 2). *I. unicuspis* is known from several adjacent Great Lakes drainages in Indiana, Illinois and Michigan (2, 5, 7). *I. castaneus* can be readily distinguished from *I. unicuspis* because *I. castaneus* possesses bicuspid teeth in the circumoral series, and bicuspid teeth are lacking in *I. unicuspis* (as its name implies).

The previous records of *I. castaneus* from the Saint Joseph River drainage in Indiana are based on a specimen collected in the Saint Joseph River 6 km E of South Bend in 1930 and a report from the Elkhart River at Goshen in 1890 (1, 2). Thus, our specimens represent the first report of the continued existence of the species in the Saint Joseph River drainage of Indiana in over 50 years.

There are few other published records for *I. castaneus* in Indiana. A confirmed record from the East Fork of the White River in Lawrence County and several records from the Lake Michigan drainage in Lake County are the only others reported by Gerking (1) for the species in the state. Rohde and Lanteigne-Courchene (5) show additional localities in the Wabash drainage of Indiana. Although there are no records of *I. castaneus* from northeastern Illinois (6), there are many records from southwestern Michigan (5). Starret et al. (7) suggested that the range of *I. castaneus* in Illinois has withdrawn southward.

The ammocoetes collected at Christiana Creek and Turkey Creek could be *I. castaneus, I. fossor* or *I. unicuspis*, since all have similar myomere counts, and other morphological characters useful in distinguishing ammocoetes are unknown (6, 8). As with *I. unicuspis*, there apparently are no definite records of *I. fossor* from the Saint Joseph River drainage in Indiana, although a number of records exist from adjacent drainages (2, 5). An 1895 record Gerking (1) lists for *I. fossor* for Turkey Creek was considered questionable by Hubbs and Trautman (2). Until the presence of *I. fossor* and *I. unicuspis* in the Saint Joseph River drainage is established, we suggest that ammocoetes collected during the current study and those reported by Marenchin and Sever (3) are most likely *I. castaneus*.

Our collections also yielded two species of fish not reported for tributaries of the Saint Joseph River by Marenchin and Sever (3). Single specimens of *Amia calva* were collected on 20 August and 18 September, 1981, and two *Erimyzon sucetta* were collected on 18 September. Both of these species were reported from northern Elkhart County by Gerking (1), but our specimens represent the first records of these species in the drainage since 1945.

In summary, the collection of three adult *I. castaneus* leads us to suggest that ammocoetes reported by Marenchin and Sever (3) from the Saint Joseph River drainage should be assigned to that species. Our collections represent the first

reports of *I. castaneus* in over 50 years and of *A. calva* and *E. sucetta* in over 35 years from waters of the Saint Joseph River drainage in Indiana (1, 2). These species should be added to the list of 40 other species of fish reported by Marenchin and Sever (3) from tributaries of the Saint Joseph River in Elkhart County.

Acknowledgments

We thank L. M. Page of the Illinois Natural History Survey for confirming the identification of the *I. castaneus*. We thank R. C. Cashner of the University of New Orleans for confirming the identification of the *E. sucetta*.

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There are four things that make this world go round: love, energy, materials, and information. We see about us a critical shortage of the first commodity, a near-critical shortage of the second, increasing shortage of the third, but an absolute glut of the fourth.

—ROBERT A. DAY

In the preface to his book *How to Write and Publish a Scientific Paper*,[1] Day uses the four words energy, information, love and materials to underscore his general advice to authors of scientific papers. Before he presents more specific advice on the writing of conference reports, theses, and review papers, and continuing in his preface, Day advises authors on how to alleviate the problem of the glut of information.

> We in science, of necessity, must contribute to the glut. But let us do it with love, especially love of the English language, which is the cornerstone of our intellectual heritage; let us do it with energy, the energy we need to put into the scientific paper so that the reader will not need to use much energy to get the information out of the paper; and let us husband our materials, especially our words, so that we do not waste inordinate quantities of paper and ink in trying to tell the world more than we know.

That which is appropriate for the writing of all other components of a scientific or scholarly paper is also appropriate for the writing of the abstract.

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1. DAY, R. A. 1979. How to write and publish a scientific paper. ISI Press, Phila delphia, Pa.
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PROCEEDINGS

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Joseph R. Siefker	1980	Indiana State University
Michael J. Sinsko	1981	Indiana State Board of Health
Tracy M. Sonneborn	1953	Indiana University
Russell K. Stivers	1970	Purdue University
B. K. Swartz, Jr.	1971	Ball State University
James Thorp	1960	Indiana University Medical Center
Robert E. Van Atta	1976	Ball State University
Claude F. Wade	1975	Indianapolis, IN
Gertrude L. Ward	1971	Earlham College
Wm. John Wayne	1967	University of Nebraska
Walter J. Weber	1973	Indianapolis, IN
J. Dan Webster	1967	Hanover College
Eugene D. Weinberg	1959	Indiana University
Winona H. Welch	1935	Greencastle, IN
Frank Welcher	1950	Indianapolis, IN
John O. Whitaker	1976	Indiana State University
Joe L. White	1960	Purdue University
Grant T. Wickwire	1935	Saybrook, CT
Charles E. Wier	1967	AMAX Coal Company
Dan Wiersma	1977	Purdue University
Donald R. Winslow	1977	Indiana University
Bernard S. Wostman	1978	University of Notre Dame
Willard F. Yates, Jr.	1973	Butler University
Alan C. York	1979	Purdue University
F. N. Young, Jr.	1955	Indiana University
Howard R. Youse	1963	Greencastle, IN
Harold L. Zimmack	1978	Ball State University

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Spring Meeting	April 23-24, 1971	Connersville
Fall Meeting	October 28-29, 1971	Richmond
1972		
Spring Meeting	April 28-29, 1972	Notre Dame
Fall Meeting	November 2-4, 1972	Notre Dame
1973		
Spring Meeting	May 11-12, 1973	Nashville
Fall Meeting	October 26-27, 1973	Indianapolis
1974		
Spring Meeting	May 3-4, 1974	Spencer
Fall Meeting	October 31-November 2, 1974	Greencastle
1975		
Spring Meeting	April 25, 1975	Brown County
Fall Meeting	October 30-31, 1975	Indianapolis
1976		
Spring Meeting	April 23, 1976	New Harmony
Fall Meeting	November 4-5, 1976	Valparaiso
1977		
Spring Meeting	April 22, 1977	Indianapolis
Fall Meeting	October 27-28, 1977	Indianapolis
1978		
Spring Meeting	April 28, 1978	Connersville
Fall Meeting	November 2-3, 1978	Anderson
1979		
Spring Meeting	April 27-28, 1979	St. Meinrad
Fall Meeting	October 18-19, 1979	North Manchester
1980		
Spring Meeting	April 25-26, 1980	Geneva Center
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